PB84-174168

Wastewater Recycle and Reuse Potential for Indirect Discharge Textile Finishing Mills
Volume 2. Six Mill Engineering Reports

Sverdrup and Parcel and Associates, Inc.
St. Louis, MO

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

Mar 84

U.S. Department of Commerce
National Technical Information Service
NTIS

PB84-174168

EPA-600/2-84-070b
March 1984

WASTEWATER RECYCLE AND REUSE POTENTIAL FOR INDIRECT DISCHARGE TEXTILE FINISHING MILLS

Volume 2. Six Mill Engineering Reports

by

Jon F. Bergenthal

Sverdrup & Parcel and Associates, Inc.
St. Louis, Missouri 63101

Contract No. 68-02-3678

EPA Project Officer: Robert V. Hendriks

Industrial Environmental Research Laboratory
Utilities and Industrial Processes Division
Research Triangle Park, NC 27711

Prepared for

U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

385

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-84-070b	2.	3. RECIPIENT'S ACCESSION NO. PB84 174168
4. TITLE AND SUBTITLE Wastewater Recycle and Reuse Potential for Indirect Discharge Textile Finishing Mills; Volume 2. Six Mill Engineering Reports		5. REPORT DATE March 1984 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Jon F. Bergenthal		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Sverdrup and Parcel and Associates, Inc. 801 North Eleventh St. Louis, Missouri 63101		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. 68-02-3678 (Phases 1 and 2)
12. SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Industrial Environmental Research Laboratory Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED Final; 4/81-6/83 14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES IERL-RTP project officer is Robert V. Hendriks, Mail Drop 63, 919/541-3928.

16. ABSTRACT The report gives detailed information on a variety of wastewater recycle/reuse technologies that allow textile finishing mills to reduce the volume of wastewater and the amount of pollutants discharged to publicly owned treatment works. (NOTE: Dyebath reconstitution is described separately.) Many of these technologies have been demonstrated full-scale, but only a few have become widely applied in the textile industry. Technical and economic factors affect the application of most of these technologies at a given mill; thus, each must be considered under its own mill-specific conditions. Included for each described technology are a description, its environmental benefits, recycle and treatment system schematics, design criteria, technical factors that limit or enhance its application, capital and yearly costs, factors that affect its economic fasibility, its current applications, and references for further information. The information in this report is based on a survey of the literature, discussions with equipment/process vendors and researchers, and engineering studies at six textile finishing mills. The six mills provide a good cross-section of the variety of products, fibers, manufacturing processes, and potential recycle/reuse technologies encountered in textile finishing. Volume 2 of the report consists of the six mill engineering reports.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Textile Finishing	Stationary Sources	13H
Waste Water	Recycling	
Circulation		14G
Waste Treatment		

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 386
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

Over 80 percent of textile finishing mills discharge their wastewater to publicly owned treatment works. A variety of wastewater recycle technologies has been developed to allow these mills to reduce the volume of wastewater and amount of pollutants discharged.

Only a few of these technologies have become widely applied in the textile finishing industry. With most of these technologies, specific technical and economic factors affect their application at a given mill; thus each application must be considered under its own mill-specific conditions.

This report presents detailed information on textile wastewater recycle/reuse technologies. Included for each are a description of the technology, its environmental benefits, recycle system and treatment system schematics, design criteria, a discussion of technical factors that limit or enhance the application of the technology, capital and yearly costs, an examination of factors that affect the economic feasibility of the technology, listings of current applications of the technology, and references for further information.

The information in this report is based on a survey of the literature, discussions with technology vendors and researchers, and engineering studies conducted at six textile finishing mills. The six mill engineering reports appear in Volume 2 of this report.

This report is submitted in accordance with Contract Number 68-02-3678 between the U.S. Environmental Protection Agency and Sverdrup & Parcel and Associates, Inc. It documents the work performed under Phases I and II of the contract. A future report (Phase III) will cover a detailed investigation of dyebath reconstitution and reuse.

TABLE OF CONTENTS

Page

Mill C-2, Nylon Carpet Tufting and Dyeing . . . . A-i
Mill W-3, Woven Fabric Preparation and Printing . . . . B-i
Mill W-4, Woven Fabric Finishing . . . . C-i
Mill W-8, Woven Industrial Fabric Finishing . . . . D-i
Mill W-9, Woven Fabric Finishing . . . . E-i
Mill Y-4, Acrylic Yarn Dyeing . . . . F-i

MILL SURVEY REPORT

MILL C-2
NYLON CARPET TUFTING AND DYEING

SUMMARY

Mill C-2 is a nylon carpet tufting and dyeing facility. The bulk of the 1 mgd wastewater at this mill is associated with acid dyeing of carpet in becks. Figure 1 presents the basic manufacturing processes and recycle/reuse options considered, and summarizes both technical and economic feasibility as well as further research needs for each alternative. Table 1 illustrates the projected savings, costs, and paybacks associated with recycle/reuse options considered at this mill.

The most promising recycle/reuse option at this mill is dyebath reconstitution at one or more dyebecks. Tighter control of dyebeck cooling water will also result in significant savings.

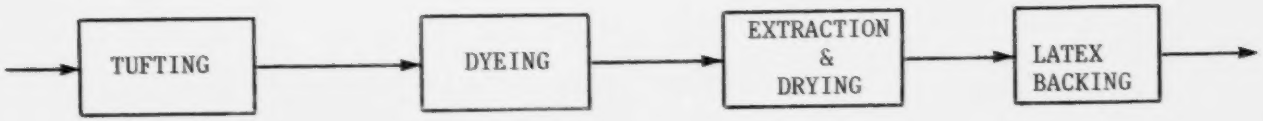
RECOMMENDATIONS

Control of Dyebeck Cooling Water

1. The water supply line to one dyebeck should be metered to compare the theoretical cooling water requirements to actual cooling water requirements.
2. The becks should be automatically programmed for dyebeck cooling water shutoff when the dyebeck temperature drops below 150°F during cooling.

Dyebath Reconstitution

1. The feasibility of performing most dyeing at this mill with only a few dyestuffs should be investigated.
2. Testing of reused dyebaths should be conducted to determine any adverse effects on dyeing quality. Sequencing of colors to enable reuse should be determined and evaluated.
3. Actual chemical savings should be determined in reuse investigations.
4. More detailed procedures for dyebath reuse at full-scale need to be developed for this mill.


TUFTING
DYEING
EXTRACTION & DRYING
LATEX BACKING

Technologies Evaluated	Feasibility		Data Needs
	Technical	Economic	
Dye Wastewater Decolorization (Cl_2) & reuse	feasible	marginal	Investigate formation of chlorinated compounds
Decolorization (Act Carbon) & reuse	feasible	not promising	--
Dyebath reconstitution	promising	promising	Demonstration
In-beck heat transfer	feasible	not promising	--

Figure 1. Manufacturing Processes and Potential Recycle/Reuse Technologies at Mill C-2.

TABLE 1

SUMMARY OF ECONOMIC AND ENVIRONMENTAL BENEFITS OF RECYCLE/REUSE OPTIONS

Recycle/Reuse Scheme	Net Annual Savings	Capital Cost	Payback (years)	Flow Reduction		COD Reduction	
				gpd	% Total	lb/day	% Total
Chlorine Oxidation of Dyehouse Wastewater	$350,000	$1,067,000	3	755,000	75	4,400	75
Carbon Adsorption of Dyehouse Wastewater	($70,000)	$2,070,000	Net Operating Costs	848,000	84	*	*
Dyebath Reconstitution (10 becks)	$222,000	$ 242,000	1	166,000	17	1,470	25
Control of Dyebeck Cooling	$ 37,000	0	--	205,000	20	0	0
Dyebeck Cooling by Heat Transfer	$ 70,000	$ 641,000	9	94,000	9	0	0

* Insufficient information

TABLE OF CONTENTS

Page

Summary ii
Table of contents v

I. INTRODUCTION 1
  Facility Description 1
  Manufacturing Processes 1
  Overall Mass and Energy Balances 6
  Evaluation of Recycle/Reuse Technologies 9

II. CHLORINE OXIDATION OF DYEHOUSE WASTEWATER 13
  Description of Manufacturing Process and Proposed Modification 13
  Technical Feasibility and Design Criteria 17
  Economic Feasibility 19
  Environmental Benefits 20
  Conclusions 20

III. CARBON ADSORPTION TREATMENT OF DYEHOUSE WASTEWATER 24
  Description of Manufacturing Process and Proposed Modification 24
  Technical Feasibility and Design Criteria 24
  Economic Feasibility 28
  Environmental Benefits 28
  Conclusions 30

IV. RECONSTITUTION OF DYEBATH WASTEWATER 31
  Description of Manufacturing Process and Proposed Modification 31
  Technical Feasibility and Design Criteria 33

TABLE OF CONTENTS (Continued)

Page

Economic Feasibility 34
Environmental Benefits 37
Conclusions 39

V. COOLING WATER REQUIREMENTS 40
Description of Manufacturing Process and Proposed Modification 40
Technical Feasibility and Design Criteria 40
Economic Feasibility 40
Environmental Benefits 43
Conclusions 43

VI. NONCONTACT COOLING OF DYEBATH WATER 44
Description of Manufacturing Process and Proposed Modification 44
Technical Feasibility and Design Criteria 44
Economic Feasibility 46
Environmental Benefits 46
Conclusions 46

References 48

SECTION I
INTRODUCTION

Mill C-2 is a major carpet tufting and dyeing facility located in the Southeast. This report assesses the applicability of three technologies - chlorine decolorization, activated carbon, and dyebath reconstitution - to enable reuse of process wastewaters.

FACILITY DESCRIPTION

The total efforts of Mill C-2 are geared toward the production of finished carpet for domestic and commercial use. Over 90 percent of the carpet produced here is nylon fiber carpet. The minor remaining portion produced here is polyester carpet. The principal manufacturing processes involved in carpet production at Mill C-2 are tufting, piece dyeing, and latex backing. These processes are described below.

MANUFACTURING PROCESSES

Tufting

This plant receives yarn to product specifications from associated company operations or open market purchases of prepared yarn. Individual packages (4 to 8 lbs) of yarn are combined in a creel to make up the required number of yarn ends to supply the proper gauge for the tufting machine. From the creel the yarn is fed to a needling (tufting) machine. There are several such machines at this plant. These machines sew the yarn into a primary backing material called scrim. The machine can be mechanically set to produce loop pile, cut pile, or a desired pattern. No wastewater is generated from any aspects of the tufting operation.

Dyeing

Following tufting, the product is piece dyed in an open beck. Several medium size becks are used here. The beck is filled with city water estimated by mill personnel to average 53°F. The required chemical additions and dye formulations are prepared on the plant's second level. Once the proper amount and type of dye and additives have been prepared, they are fed into the beck through a false front. Chemicals are added first and circulate for about ten minutes before the dye is added. Among the chemical additives that may be introduced into the beck are anti-foam agents (non-silicone, mineral oil base), monosodium or trisodium phosphates to control pH, leveling agents (fatty acids) or ethylene oxide condensates for even dye dispersion on the face of the carpet, and polyamide derivative softening agents. Acid dyes (azo and diazo compounds) are used to dye nylon carpet, and dispersed dyes are used for dyeing polyester carpet. Fabric loading, circulation of chemicals, and circulation of dyes usually requires a total of 20 to 30 minutes.

Superheated steam (400°F) is used to heat the dyebath. Steam is introduced into the beck through the same open sparge (false front) used for introducing the dye formulation. The rate of rise in temperature and dye strike (dyeing) temperature is dependent upon the dyestuff and the yarn in the carpet. Usually the dyebath temperature is raised at a rate of two to three degrees per minute until the dye strike temperature of 180°F for low temperature dyeing or 209°F to 213°F (i.e. rolling boil) for high temperature dyeing is reached. Thus, the heating procedure usually requires 45 minutes to an hour. Once the dye strike temperature is reached, carpet circulates through the dyebath for 45 minutes to one hour. The various parameters described above are individually programmable for each beck and cycle.

After the carpet has been circulated for the required length of time, the temperature is lowered to 180°F and the carpet is checked for proper shade. If this inspection shows that the desired shade has not yet been acquired, additional dye is added and the dyebath is again heated to the dye strike temperature. The process of adding additional dye, reheating, and reinspecting is referred to as an "add". Each add will require approximately an hour. Typically there will be one to four or more adds. Over a period of time, the number of adds per dyeing cycle averages one and a half. A dyeing cycle (length of time between carpet loading and its removal from the beck) requires three hours if there are no adds. The average cycle lasts 4½ hours.

Once an inspection shows that the carpet has reached the desired shade, a portion of the dyebath is drained and replaced with cold water to gradually cool the bath. Sufficient cooling is achieved when the bath temperature reaches 150°F. This bath is then dumped and the beck is refilled for cooling and rinsing.

Extraction and Drying

When the carpet is cool enough to handle, it is removed from the beck and goes through a vacuum extractor for water removal. The carpet is dipped through a water bath to ensure even moisture distribution as the carpet passes through the extractor. As the carpet enters the extractor, the weight of the carpet and the weight of the entrapped water are about equal. Approximately two-thirds of the water is removed in this step. Following extraction, the carpet goes through a steam-heated wet goods dryer at 260°F where the moisture content is reduced to the residual level (four percent moisture for nylon).

Backcoating

The carpet is now ready to have a secondary backing of jute or polypropylene applied. A latex formulation consisting of latex and whiting is applied to the back of the primary backing. The application is controlled by electronic sensing. The secondary backing is pressed against the primary backing and the carpet is then heated by steam to achieve curing. Water cooled rollers are also used to set the latex after application of the latex coated primary backing to the secondary backing. This process is known as rubberizing, and it gives additional strength and bonding to the face yarn of the carpet.

A shearing operation sometimes follows rubberizing to give the face of the carpet an even finish. Following rubberizing (or shearing if needed), the carpet is ready for final inspection. It is then cut to customer or roll length, packaged, and shipped.

A flow schematic of the above described operations is presented in Figure I-1. These operations are shown in a plant layout drawing in Figure I-2.

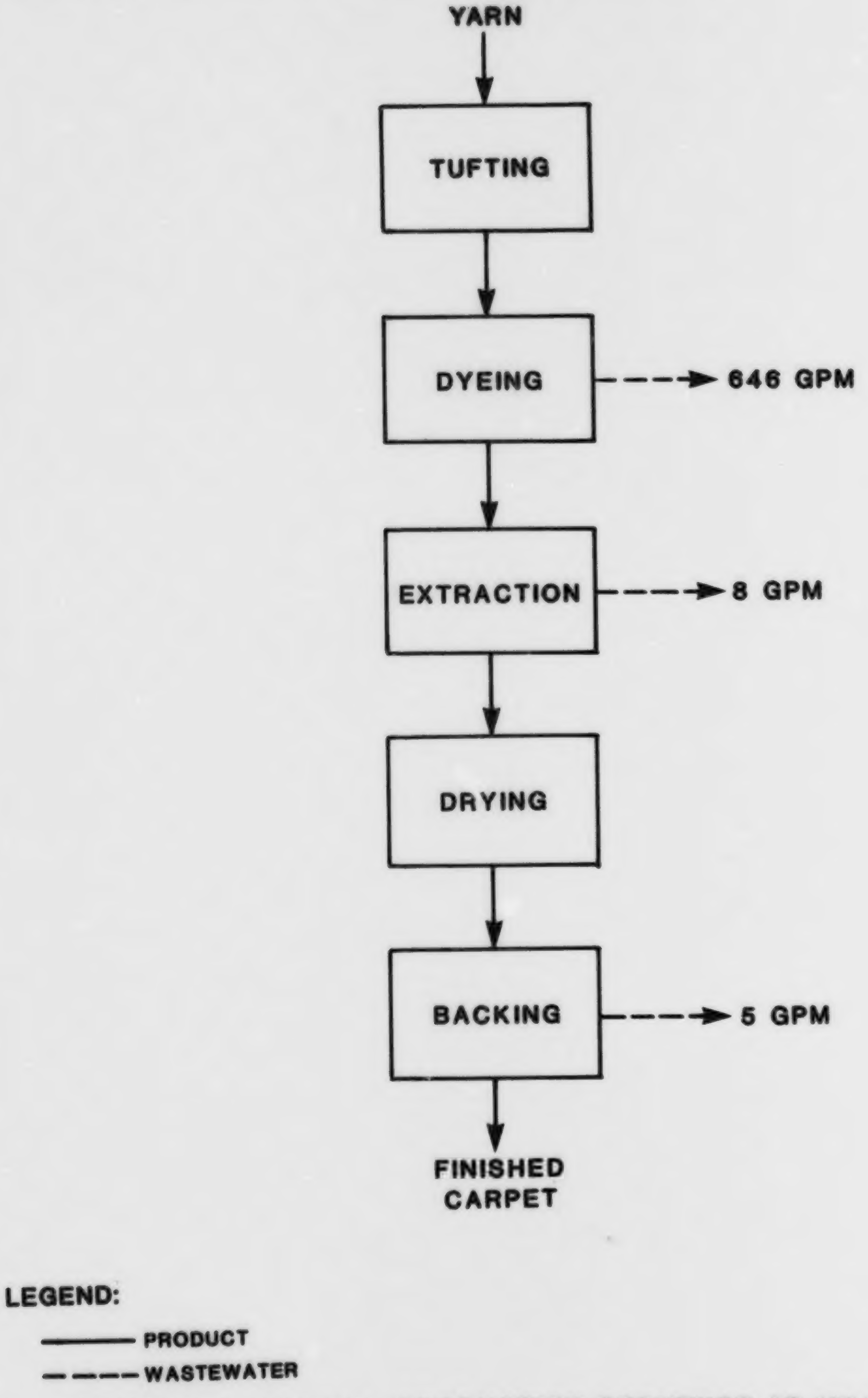

YARN
TUFTING
DYEING
646 GPM
EXTRACTION
8 GPM
DRYING
BACKING
5 GPM
FINISHED CARPET
LEGEND:
PRODUCT
WASTEWATER

FIGURE I-1. GENERAL PRODUCTION SEQUENCE AT MILL C-2.

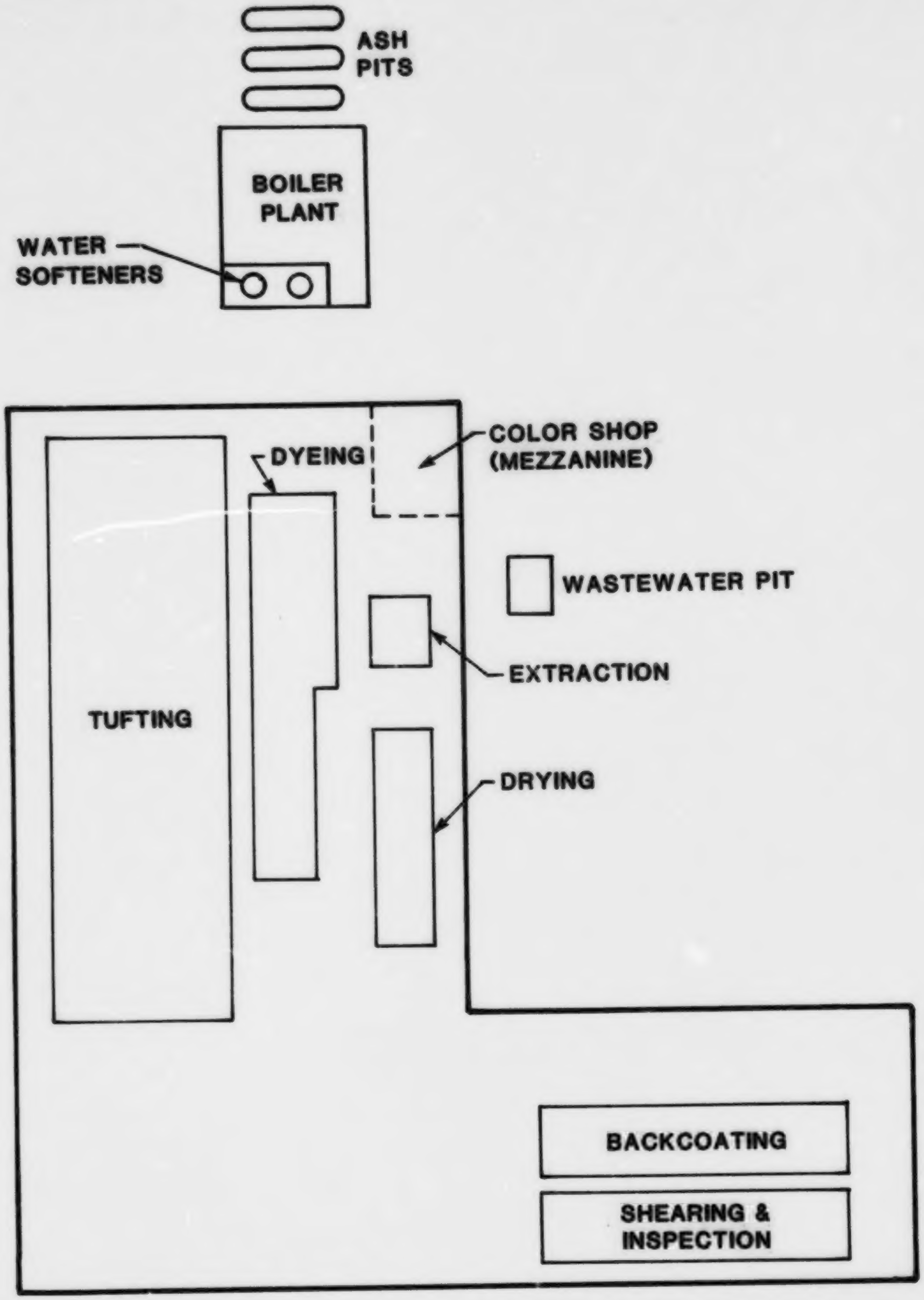

ASH PITS
BOILER PLANT
WATER SOFTENERS
COLOR SHOP (MEZZANINE)
DYEING
WASTEWATER PIT
EXTRACTION
TUFTING
DRYING
BACKCOATING
SHEARING & INSPECTION

FIGURE I-2. PLANT LAYOUT AT MILL C-2.

OVERALL MASS AND ENERGY BALANCES

Water and Wastewater Volumes and Characteristics

Mill C-2 purchases city water and passes it through a water softener prior to use. The characteristics of this softened city water are presented in Table I-1.

Water use at Mill C-2 during the sampling period was 5,716,100 gallons per week. Mill C-2 is on a five-day week, so water use averages approximately 1,143,000 gallons per working day. Making the simplifying assumption that no water is used between the last production shift on Friday and the first production shift on Monday, the following are estimated or measured workday flows for identified water use operations.

Operation	Water Use gpd	Discharge
Boiler	144,000	10,000
Ash Pit	5,000	5,000
Water Softener	21,500	21,500
Sanitary	5,000	5,000
Backcoating Noncontact Cooling	6,500	6,500
Extraction	6,000	12,000
Beck Dyeing	936,000	930,000
Miscellaneous	19,000	19,000
Total	1,143,000	1,009,000

The overall water balance is illustrated in Figure I-3.

As can be seen, most of the wastewater is generated from the piece dyeing becks. Three to five batches are run daily through each beck; the average beck size is 6,925 gallons. As noted previously, discharges from a beck during a batch consist of a partial dyebath dump during cooling as cold city water displaces dyebath water, a diluted dyebath dump, and a rinse water dump. Flows associated with a typical batch are estimated at 6,500 gallons during dyebath displacement, 6,795 gallons during the dilute dyebath dump (some water remains in carpet) and 6,925 gallons during the rinse water dump for a total discharge per batch of 20,220 gallons. The dyebath displacement flow given above is

TABLE I-1
WATER QUALITY FOR SOURCE WATER

Constituent	Concentration (mg/l)*
pH	7.2
Temperature (°F)	68
Color (ADMI)	6
BOD	6.2
COD	23
TDS	130
TSS	1
TS	130
Turbidity (NTU)	<0.1
Phenolics	<0.05
Chloride	6.9
Alkalinity	90
Oil & Grease	13
Calcium	0.25
Magnesium	0.12
Sodium	0.96
Total Phosphorus	0.04

*Sampled on April 14, 1982.

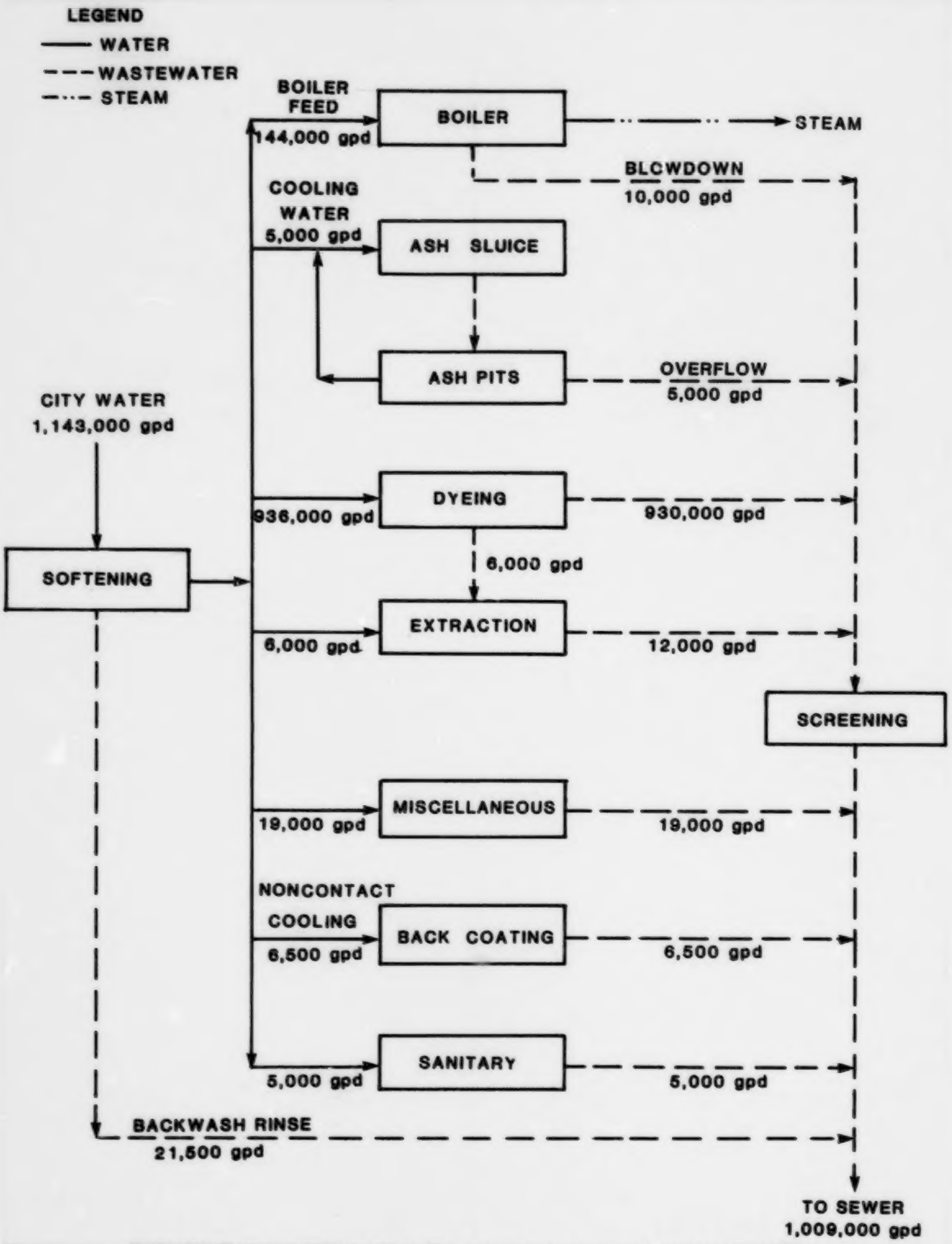

LEGEND
WATER
WASTEWATER
STEAM
BOILER FEED
144,000 gpd
BOILER
STEAM
BLOWDOWN
10,000 gpd
COOLING WATER
5,000 gpd
ASH SLUICE
ASH PITS
OVERFLOW
5,000 gpd
CITY WATER
1,143,000 gpd
DYEING
936,000 gpd
930,000 gpd
6,000 gpd
SOFTENING
EXTRACTION
6,000 gpd
12,000 gpd
SCREENING
MISCELLANEOUS
19,000 gpd
19,000 gpd
NONCONTACT COOLING
6,500 gpd
BACK COATING
6,500 gpd
SANITARY
5,000 gpd
5,000 gpd
BACKWASH RINSE
21,500 gpd
TO SEWER
1,009,000 gpd

FIGURE I-3 WATER USE AND WASTEWATER DISCHARGE

larger than the flow estimated by mill personnel. It was calculated based on random temperature measurements during the sampling period that showed an average temperature reduction of 64°F for the dyebaths. Extra cooling water was being used to cool the dyebaths well below 150°F to an average temperature of 114°F.

Dyehouse wastes are screened for lint removal before passing into a sump. In this pit, they mix with boiler plant and water softener wastewater. This wastewater is then pumped downflow through another screen before combining with sanitary wastes and other mill wastewaters for discharge to the municipal wastewater treatment plant.

Wastewater samples were collected and analyzed from the becks and effluent locations. Conventional and nonconventional textile pollutant results for the dyebath before and after dilution, rinse water, dyehouse wastes prior to the first screen, and combined wastes after the first screen are presented in Table I-2. Daily mass loadings of these pollutants are listed in Table I-3. Other wastewater constituents that affect recycle are discussed below under the appropriate recycle technologies.

Energy

Energy requirements at Mill C-2 are met using coal and electricity. Steam for the dye becks and other needs is provided by a conventional coal-fired boiler plant. Electricity is used for machinery operation and lighting. No heat exchangers are present at this facility.

Materials

Based on records during the sampling period, Mill C-2 processes over 40 batches of carpet most weekdays, with slightly higher production on Mondays and significantly lower production on Fridays. The average carpet face yarn weight per batch is 1,524 lbs.

EVALUATION OF RECYCLE/REUSE TECHNOLOGIES

The recycle/reuse technologies applicable to Mill C-2 that are evaluted in this report are the following:

TABLE I-2

WASTEWATER CHARACTERISTICS

Wastewater Source	Batch or Date	Concentrations (mg/l)				
		BOD_5	COD	TSS	Phenolics	pH
Dyebath Prior to Dilution	1	520	3,000	14	<.050	7.7
	2	41	2,300	4	<.050	7.3
	3	470	3,300	8	.071	9.0
	4	810	3,300	7	.530	9.1
	5	850	3,000	10	.050	7.8
	6	1,390	4,530	6	.050	8.8
	Average	680	3,240	8	.130	--
Dilute (Cooled) Dyebath	1	280	1,900	8	.180	7.9
	2	79	950	<1	<.050	7.4
	3	430	1,600	<1	<.050	8.8
	4	340	1,560	2	<.050	8.3
	5	520	1,830	8	<.050	7.8
	6	460	1,250	3	.380	8.3
	Average	350	1,520	4	.130	--
Dye Beck Rinsewater	1	40	760	6	<.050	7.9
	2	11	230	<1	.560	7.6
	3	80	270	<1	.240	8.1
	4	180	270	2	.540	8.0
	5	180	430	2	<.050	7.8
	6	29	200	2	.230	8.0
	Average	87	360	2	.280	--
Final Effluent*	4/13/82	270	750	18	<.050	7.8
	4/14/82	340	650	8	.190	7.3
	4/15/82	320	790	2	.064	7.5
	4/16/82	320	720	13	<.050	7.6
	4/20/82	280	700	10	<.050	7.6
	Average	310	720	10	.080	--

* Samples of 4/13 and 4/14 from dyehouse discharge prior to first screen. Other samples from pit.

TABLE I-3

POLLUTANT LOADINGS

Wastewater Source	Flow		BOD_5		COD		TSS		Phenolics	
	gal/day	% Total	lb/day	% Total	lb/day	% Total	lb/day	% Total	lb/day	% Total
Dyebath	299,000	31	1,700	68	8,080	138	20	24	0.32	49
Dilute Dyebath	312,500	32	910	36	3,960	67	10	12	0.34	52
Rinsewater	318,500	33	230	9	960	16	5	6	0.74	114
Other*	48,000	5	(340)	--	(7,130)	--	47	--	0.75	--
Final Effluent	978,000	100	2,500	100	5,870	100	82	100	0.65	100

* Miscellaneous streams such as boiler, ash pit, water softener, extraction, etc., plus unaccounted for balance.

1. Dyehouse wastewater - chlorine oxidation for decolorization.
2. Dyehouse wastewater - activated carbon for decolorization.
3. Exhausted dyebath wastewater - reconstitution.
4. Tighter control of water used for cooling.
5. Diluted dyebath wastewater - alternative cooling with heat transfer coils to enable water use reduction.

SECTION II

CHLORINE OXIDATION OF DYEHOUSE WASTEWATER

DESCRIPTION OF MANUFACTURING PROCESS AND PROPOSED MODIFICATION

Dyeing is performed at Mill C-2 from Sunday evening through Friday afternoon. In a typical week, slightly over 200 batches would be dyed for a total face yarn weight of approximately 322,000 pounds. Dyehouse wastes during this period will be approximately 4,326,000 gallons. During mid-week, typical daily figures would be as follows: 70,000 pounds and 942,000 gpd. A schematic of the flows, production, and chemicals associated with a typical batch is presented in Figure II-1. Table II-1 presents the wastewater characteristics associated with these flows.

It is estimated that 92 percent of the dyehouse wastewater is associated with acid dyeing. However, there are frequently periods where no disperse dyeing is performed and at these times all dyehouse flows are comprised of acid dye wastewater. Thus, 942,000 gpd is the basis for examining design criteria and the economics of chlorine oxidation at this mill. Some scheduling, piping, and/or process control modifications will be needed in order to segregate the relatively infrequent disperse dye dumps from the acid dye wastewaters. Although disperse dyes are treatable by chlorine oxidation, a longer reaction time is required for decolorization than with acid dyes.

A comparison of the existing and revised process schematic incorporating chlorine oxidation is illustrated in Figure II-2. An equalization tank is necessary prior to the chlorine oxidation system to enable full blending of all the treatable water and thus prevent sudden changes in the wastewater being treated. The wastewater next enters a series of treatment tanks in which it is decolored by chlorine oxidation. Liquid caustic is used as a buffer to maintain the proper pH during oxidation, and sulfur dioxide gas is employed as an antichlor. Decolored water is next filtered to remove larger particulates and is stored briefly before being returned to the dyehouse.

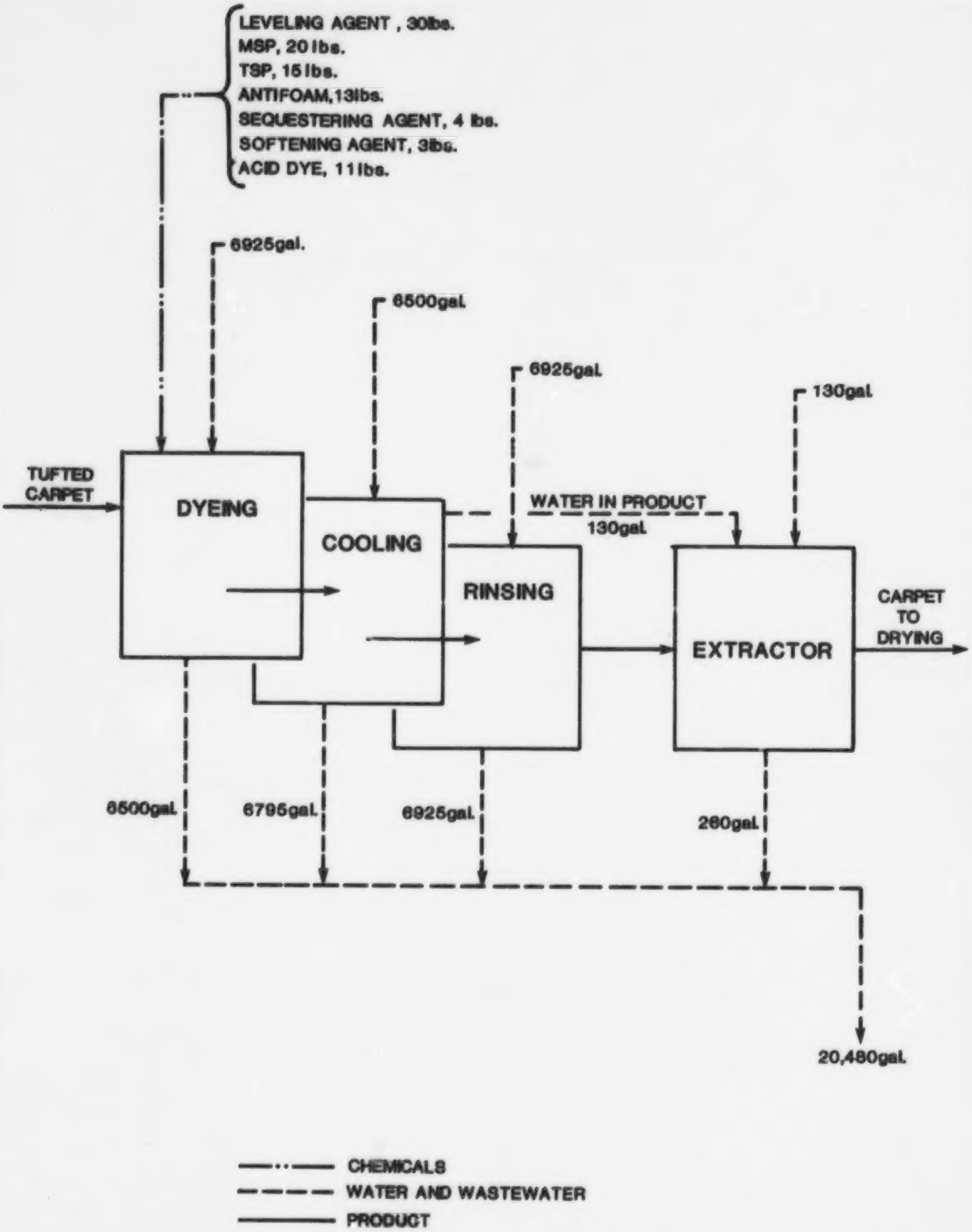

LEVELING AGENT , 30lbs.
MSP, 20 lbs.
TSP, 15 lbs.
ANTIFOAM, 13lbs.
SEQUESTERING AGENT, 4 lbs.
SOFTENING AGENT, 3lbs.
ACID DYE, 11lbs.
6925gal.
6500gal.
6925gal.
130gal.
TUFTED CARPET
DYEING
COOLING
RINSING
WATER IN PRODUCT
130gal.
EXTRACTOR
CARPET TO DRYING
6500gal.
6795gal.
6925gal.
260gal.
20,480gal.
CHEMICALS
WATER AND WASTEWATER
PRODUCT

FIGURE II-1. FLOWS WITH TYPICAL DYEING CYCLE

TABLE II-1
DYE WASTEWATER CHARACTERIZATION

Parameter	Average Concentrations (mg/l)			
	Dyebath	Dilute Dyebath	Rinsewater	Final Effluent
pH (median)	8.3	8.1	8.0	7.6
Temperature [°F (°C)]	178 (81)	114 (46)	75 (24)	105 (41)
BOD	680	350	87	310
COD	3,240	1,520	360	720
TS	1,990	980	320	590
TDS	1,500	740	250	470
TSS	8	4	2	10
Chloride	21	13	7.0	56
Hardness (as $CaCO_3$)	0	--	--	16
Oil & Grease	63	50	22	110
Phenolics	.130	.130	.280	.080
Total Phosphorus	110	62	29	23
Turbidity (NTU)	60	46	14	31
Color (ADMI)	1,440	690	520	430
Alkalinity (as $CaCO_3$)	210	150	100	97
Total Carbon (%)	--	--	--	0.34
Fluoride	--	--	--	0.14
MBAS (as LAS)	--	--	--	7
Conductivity (umhos/cm)	--	--	--	310
Sulfate (as SO_4)	--	--	--	7.2
Calcium	0.60	0.36	0.21	4
Magnesium	0.53	0.32	0.14	1.7
Sodium	3.7	2.2	1.3	26

Selected metals were also analyzed in the wastewater from one final effluent sample and the results were as follows: As - <0.005 mg/l; Cd - <0.1 mg/l; Cr - <0.1 mg/l; Cu - <0.1 mg/l; Fe - 0.38 mg/l; Pb - <0.1 mg/l; Ni - <0.1 mg/l; Zn - <0.1 mg/l; K - 1.8 mg/l; Sn - <1.0 mg/l; Al - 0.50 mg/l.

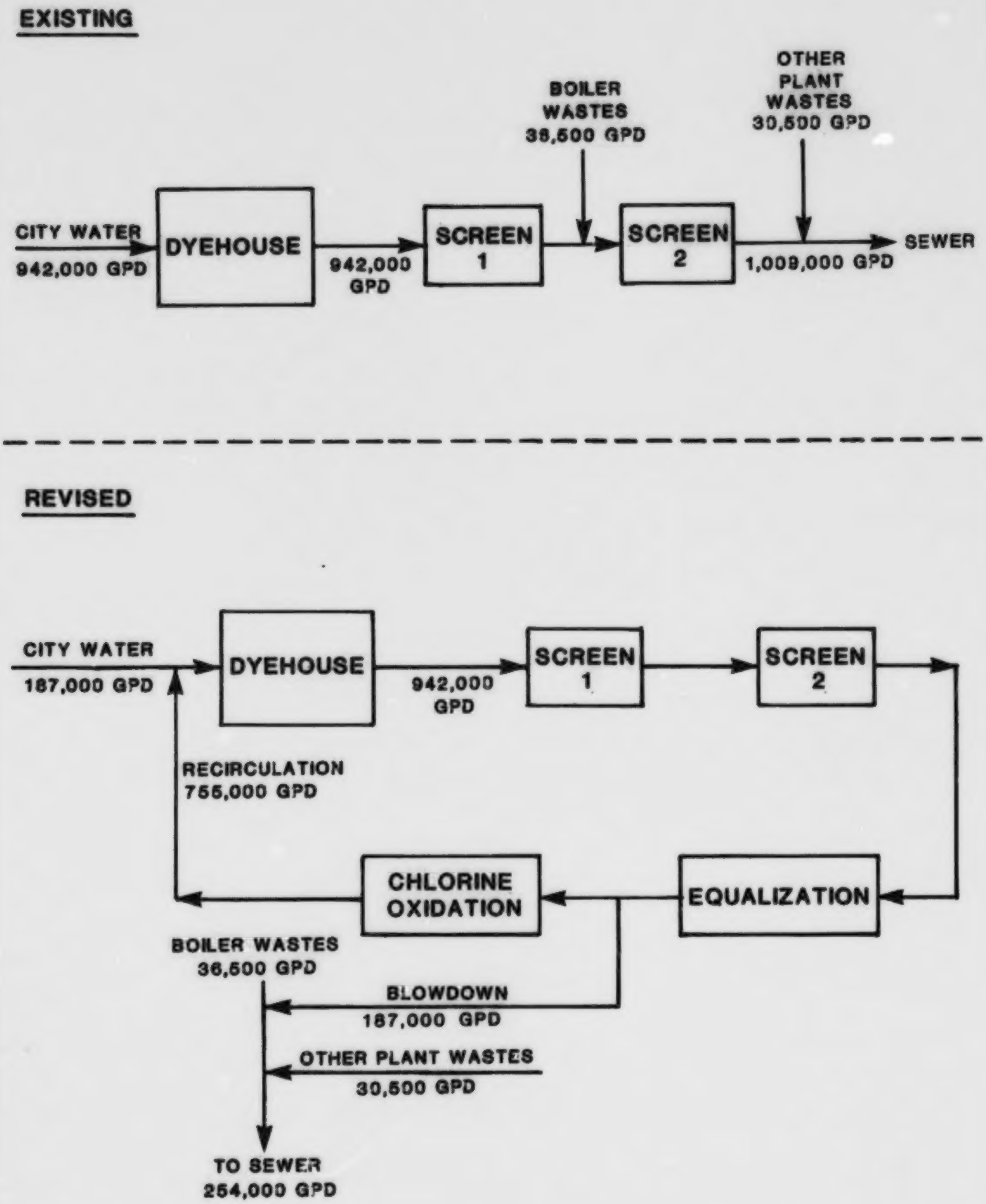

EXISTING
BOILER WASTES 36,500 GPD
OTHER PLANT WASTES 30,500 GPD
CITY WATER
942,000 GPD
DYEHOUSE
942,000 GPD
SCREEN 1
SCREEN 2
1,009,000 GPD
SEWER
REVISED
CITY WATER
187,000 GPD
DYEHOUSE
942,000 GPD
SCREEN 1
SCREEN 2
RECIRCULATION
755,000 GPD
CHLORINE OXIDATION
EQUALIZATION
BOILER WASTES
36,500 GPD
BLOWDOWN
187,000 GPD
OTHER PLANT WASTES
30,500 GPD
TO SEWER
254,000 GPD

FIGURE II -2 COMPARISON OF EXISTING AND REVISED DYEHOUSE WASTEWATER TREATMENT SYSTEMS EMPLOYING CHLORINE OXIDATION

TECHNICAL FEASIBILITY AND DESIGN CRITERIA

Literature and Previous Applications

Investigations by Perkins, et al. (reference 1), and Textile Systems, Inc. (TSI) have demonstrated that acid dyes can be decolored by chemical oxidation. Both ozone and chlorine have been successful in producing a water suitable for reuse in dyeing, and test dyeings over a series of reuse applications have been acceptable.

Oxidation has been shown to decrease the molecular weight of dye molecules by attacking amide and other molecular linkages, thereby destroying chromophoric groups and decoloring the wastewater.

Thus far, only oxidation by chlorine has been employed in full-scale applications for dye wastewater decolorization, and this has been primarily for acid dyes. Ozone has not been applied because of costs of generation, practicality, and safety hazards, but it may become more competitive as improvements are made.

A more detailed summary of the research and applications to date is found in Volume 1.

Bench Scale Results

Bench scale chlorine decolorization tests were performed on two dye wastes, two rinse water wastes, and all five final effluent samples. Table II-2 presents a summary of the results. The final effluent samples were observed to decolor substantially at a dose of 50 mg/l chlorine, but retained a straw yellow color that remained even at a chlorine dose of 100 mg/l. Decoloring of dyebath and rinse waters from individual becks did not provide conclusive results.

Based on these results, it appears that the combined dyeing wastewater (final effluent except for boiler wastes and other miscellaneous uses) will decolor at a chlorine dose of 50 mg/l. The residual yellow color should not normally interface with dyeing, according to TSI research, but this should be investigated before proceeding further with this recycle technology.

TABLE II-2

RESULTS OF BENCH-SCALE DYEBATH CHLORINATION TESTS

Wastewater		ADMI Color	
Source	Date	Initial	Final*
Dyebath	4/14/82	990	1,400
Dyebath	4/14	3,800	2,600
Rinse	4/14	220	200
Rinse	4/14	540	470
Final Effluent	4/13	820	280
Final Effluent	4/14	380	270
Final Effluent	4/15	680	530
Final Effluent	4/16	720	350
Final Effluent	4/20	790	290

* Final color after 50 mg/l chlorine dose and 15-minute reaction time.

Technical Design Criteria

TSI has a patent covering the decolorization of textile dye wastes by chlorination. The criteria developed in previous investigations indicate a chlorine dose of 50 mg/l applied for about ten minutes to be adequate for decolorization of acid dye wastewater. Liquid caustic is used to maintain the pH at approximately 5.5. Sulfur dioxide is used as an antichlor to control residual chlorine.

An equalization tank providing approximately 30,000 gallons storage (one hour) prior to the treatment system is necessary. Using as a basis an existing system that treats similar wastes, the treatment system should be sized at one hour's flow. TSI has developed a series of standard treatment units employing this technology. For Mill C-2 with a flow of 755,000 gpd (524 gpm), the closest standard size exceeding this flow is 750 gpm. This provides a hydraulic safety factor of 1.4. Storage capacity for return to the mill is equal to the volume anticipated in two hours of average flow, i.e., 60,000 gallons.

Design criteria are summarized in Table II-3.

ECONOMIC FEASIBILITY

Cost savings are realized in the areas of water use, wastewater discharge, and auxiliary chemical use. In addition to capital costs, additional operating costs will be encountered both for labor and chemicals for the oxidation/recycle process.

Due to the low average dyehouse wastewater temperature (105°F) experienced at this mill, it is doubtful that energy savings due to this system will be significant. Energy savings would become significant if hot dyebath wastewater were a larger proportion of the total flow.

Table II-4 presents an analysis of the annual cost savings realized through dyebath oxidation and recycle. The basis of these costs and savings is as follows:

- water supply at $0.45/1,000 gallons.
- sewer use charges of $0.34/1,000 gallons.
- auxiliary (dyeing) chemical costs of $0.0764/sq yd of carpet.

- treatment chemical costs:
  - chlorine at \$0.08/lb
  - caustic at \$0.27/lb
  - sulfur dioxide at \$0.15/lb
- annual labor requirement is 4 man-years.
- water use savings are 755,000 gpd (80 percent).
- auxiliary chemical savings are 50 percent.
- treatment chemical requirements are as given in Table II-3.
- dyehouse operates 250 days/year.

The estimated capital cost (June 1982) of an oxidation recycle system for this mill is approximately \$1.1 million, including costs for the reaction and storage tanks, chemical feed and control systems, piping, pumps, electrical service, and engineering costs. The resulting payback period is about three years based on annual operating savings of nearly \$350,000.

ENVIRONMENTAL BENEFITS

The recirculation of 755,000 gpd as a result of chlorine oxidation would reduce the mill's wastewater discharge by approximately 75 percent. Since dye wastes are such a predominant portion of the discharge at this mill, reductions in pollutant loading are expected to correlate fairly closely to the reduction in hydraulic loading. Energy usage will be cut by only a minor amount, unless the volume of water used to cool and rinse carpet in the becks is significantly reduced.

CONCLUSIONS

- The literature and current full-scale operations indicate that chlorine oxidation to enable recycle should be amenable to the dye wastewaters at this plant.
- Additional testing should be performed to confirm that decolored dye wastewater can be reused without adversely affecting the quality of the dyeing.

TABLE II-3
DESIGN CRITERIA
DYEBATH OXIDATION/RECYCLE

Oxidation		
Reaction Time	minutes	10
Chlorine Dose	mg/l	50
	lb/day	315
Reaction pH		5.5
Caustic Feed	mg/l	90
	lb/day	565
Dechlorination		
Sulfur Dioxide Dose	mg/l	50
	lb/day	315
Reaction Time	minutes	5
Storage Capacity	gallons	60,000
	hours at average flow	2
Hydraulic		
Flow (average)	gpm	525
	mgd	0.75
Design Flow	gpm	750

TABLE II-4
ECONOMICS
DYEBATH OXIDATION

Annual Operating Costs

Oxidation Process Chemicals	$ 56,250
Oxidation Process Labor	60,000
Oxidation Process Maintenance	25,000
Total	$141,250

Annual Savings

Water Supply	$ 84,900
Sewer Use Charges	64,200
Auxiliary Chemicals	341,900
Energy (steam savings)	insignificant
Total	$491,000

Capital Cost

Equalization and Chlorine Oxidation	$1,067,000

Payback

Payback is estimated at approximately 3 years.

- The economics of chlorine oxidation appear marginal at this mill due to the high capital costs.
- Potential formation of chlorinated organics as a result of treatment needs to be studied.
- An approach for segregating the small amount of disperse dye wastes from the acid dye wastes needs to be developed. Perhaps disperse dyeing could be performed in one beck that is piped to bypass the chlorine oxidation treatment/recycle system.

SECTION III

CARBON ADSORPTION TREATMENT OF DYEHOUSE WASTEWATER

DESCRIPTION OF MANUFACTURING PROCESS AND PROPOSED MODIFICATION

A description of the dyeing operation at Mill C-2 has been presented previously. In addition, dyehouse flows and wastewater characteristics were detailed in the discussion of chlorine oxidation. The dyehouse flow of 942,000 gpd presented there is used as the basis for examining design criteria and the economics of activated carbon adsorption at this mill. Activated carbon has been experimentally shown to treat both acid and disperse dye wastes, and hence there is no need to segregate the minor disperse dye flow from acid dye wastes under this technology alternative.

A comparison of the existing and revised process schematic incorporating activated carbon treatment is shown in Figure III-1. Following screening for lint removal, an equalization tank is necessary to smooth out flow variations. Dual media filtration is employed prior to activated carbon treatment to remove any suspended solids that might clog the activated carbon columns. In order to avoid a build-up of impurities in the treated wastewater and provide water for backwashing the filtration and adsorption units, approximately 10 percent fresh water is used in the dyehouse daily.

TECHNICAL FEASIBILITY AND DESIGN CRITERIA

Literature and Previous Applications

M. M. Stark, B. M. Lalli, and J. L. Rizzo (reference 2), as well as others, have authored articles discussing investigations into the reuse of textile dye wastewaters through treatment with activated carbon. These studies have shown that both acid and disperse dye wastewaters are treatable in carbon adsorption systems. In one study of 13 textile manufacturers, a filtration/adsorption process using granular activated carbon achieved a median TOC removal of 94 percent and median color reductions of 98 percent O.D. units and 100 percent APHA units. In addition, a 0.5-mgd moving bed carbon adsorber system has been used to treat carpet dyeing rinsewater at Stephen Leedom Carpet Co. in

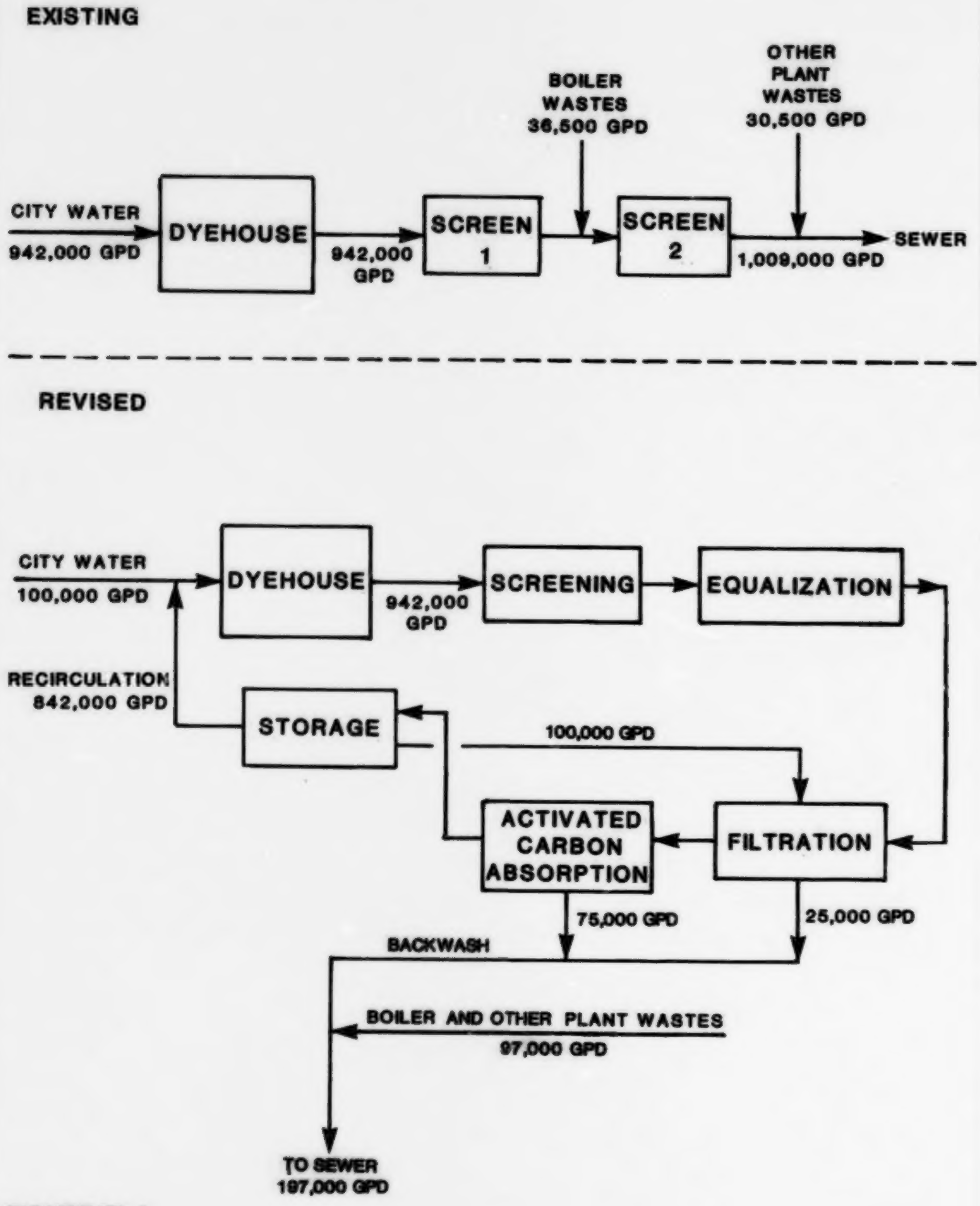

EXISTING
BOILER WASTES 36,500 GPD
OTHER PLANT WASTES 30,500 GPD
CITY WATER
942,000 GPD
DYEHOUSE
942,000 GPD
SCREEN 1
SCREEN 2
1,009,000 GPD
SEWER
REVISED
CITY WATER
100,000 GPD
DYEHOUSE
942,000 GPD
SCREENING
EQUALIZATION
RECIRCULATION
842,000 GPD
STORAGE
100,000 GPD
ACTIVATED CARBON ABSORPTION
FILTRATION
75,000 GPD
25,000 GPD
BACKWASH
BOILER AND OTHER PLANT WASTES
97,000 GPD
TO SEWER
197,000 GPD

FIGURE III-1.
COMPARISON OF EXISTING AND REVISED DYEHOUSE WASTEWATER TREATMENT SYSTEMS EMPLOYING ACTIVATED CARBON ABSORPTION

Southampton, PA; an 86,000-gpd fixed bed adsorber has been used to treat dyehouse wastewater at Harding Carpets in Collingwood, Ontario; and a 60,000 gpd pulsed bed adsorber has been used to enable reuse of rinse water from dyebecks at Westmill Carpets in Kelowna, British Columbia. These and other studies have shown the technical feasibility of using activated carbon to decolor textile dyeing wastewater.

Bench-scale testing of activated carbon to enable reuse of dye wastewaters at Mill C-2 was not performed. It was thought that if activated carbon treatment was shown to be economically feasible at this mill, based on a general preliminary assessment, more detailed design criteria could be developed at a later date based on extensive bench- or pilot-scale testing.

Technical Design Criteria

The revised treatment system for this mill is sized at 1 mgd to provide a small safety factor above the design average 848,000 gpd flow.

Due to rather limited land area available for wastewater treatment at this site, a large equalization basin cannot be employed at this site. Thus, a smaller 40,000-gallon tank providing approximately one hour of storage capacity is employed to partially balance flow and water quality fluctuations.

Filtration is considered to be necessary prior to carbon adsorption to insure a higher quality influent by removing suspended solids. This minimizes operational problems and leads to longer carbon life with less frequent backwashing. Design criteria shown in Table III-1 are those that are typical of dual-media gravity filter operation.

Activated carbon enables water reuse by adsorbing soluble dyes and hence greatly reducing color in dyehouse wastewater. For a system of this size, it is usually not economical to regenerate on-site the spent carbon, and hence fresh carbon is used for makeup. Spent carbon may either be disposed of or regenerated offsite. Table III-1 presents additional design criteria.

TABLE III-1

DESIGN CRITERIA

CARBON ADSORPTION

Equalization		
Capacity	gallons	40,000
Detention Time	hours	1
Filtration		
Type	dual media gravity	--
Media	anthracite and sand	--
Filtration Rate	gpm/sq ft	4
Run Length	hours	12
Backwash Period	minutes	15
Backwash Rate	gpm/sq ft	15
TDH	ft	14
Activated Carbon Adsorption		
Type	downflow pressure	--
Carbon	mesh size	8 to 30
Hydraulic Load	gpm/sq ft	7
Run Length	hours	24
Backwash Period	minutes	15
Backwash Rate	gpm/sq ft	18
Headloss	ft	37
Fresh Carbon Dosage	lb/MG	500
Contact Time	minutes	30
Return Water Storage		
Capacity	gallons	250,000
Supply (average water use)	hours	6

ECONOMIC FEASIBILITY

Substantial cost savings in the areas of water use and wastewater discharge are realized through recycle. Only minor energy savings are envisioned. Auxiliary chemical savings are difficult to quantify without pilot-testing, but with the possible exception of MSP and TSP, they are expected to be negligible.

Table III-2 presents an analysis of the economics of activated carbon at this mill. For the purposes of this analysis, it is assumed that no energy savings will be realized due to additional electrical requirements for the treatment system, and that MSP and TSP requirements will be reduced by 50 percent. Other bases used in this analysis follow:

- water supply at $0.45/1,000 gal.
- sewer use charges of $0.34/1,000 gal.
- MSP/TSP costs of $0.019/sq. yd. carpet
- water use savings are 842,000 gpd
- activated carbon at $0.75/lb
- 6,000 manhours/yr required for operation of treatment system
- dyehouse operates 250 days/year
- design criteria as presented in Table III-1.

As can be seen from Table III-2, the estimated capital cost of the subject treatment system is approximately $2 million. Even if pre-filtration is assumed to be unnecessary, a capital cost outlay of nearly $1.3 million is required. Regardless of which activated carbon treatment system sequence is selected, annual operation and maintenance costs exceed annual savings. Hence, activated carbon adsorption presently has net operating costs at this mill, and no payback will be realized.

ENVIRONMENTAL BENEFITS

The recirculation of 848,000 gpd as a result of carbon adsorption would reduce the mill's wastewater discharge by over 80 percent. Reductions in pollutant loadings will be somewhat smaller

TABLE III-2
ECONOMICS
CARBON ADSORPTION

Annual Operation and Maintenance Costs

Equalization	$ 0
Dual Media Filtration	39,000
Activated Carbon Adsorption	282,000
Total	$321,000
Total without Filtration	$282,000

Annual Savings

Water Supply	$ 94,700
Sewer Use Charges	71,600
Auxiliary Chemicals (MSP and TSP)	85,000
Energy	0
Total	$251,300

Capital Costs

	With Filtration	Without Filtration
Equalization (40,000 gal)	$ 25,000	$ 25,000
Dual Media Filtration	466,000	--
Activated Carbon Adsorption	621,000	621,000
Water Storage (250,000 gal)	132,000	132,000
Non-Component Costs (Piping, Electrical, etc.)	348,000	218,000
Engineering and Construction Supervision	239,000	149,000
Contingencies	239,000	149,000
Total Capital Cost	$2,070,000	$1,294,000

Payback

Even if pilot-scale testing shows that pre-filtration is unnecessary, activated carbon adsorption treatment presents Mill C-2 with net operating costs.

because of the discharge of concentrated backwash water to the sewer. Savings in energy will be small due to substantial cooling of the wastewater during treatment and the electrical requirement of treatment system operation.

CONCLUSIONS

° The literature and previous operating experience elsewhere indicate that activated carbon adsorption should provide a treated wastewater of quality sufficient for reuse at this mill.

° Land area limitations at this mill may not allow sufficient space for proper design of the treatment system. In particular, if greater equalization capacity to insure efficient operation of filtration and adsorption units is needed, the treatment system would need to be placed beyond current property lines.

° Activated carbon treatment for water reuse, either with or without prefiltration, does not appear cost effective. Annual operating costs exceed anticipated annual savings, and, therefore, there is no payback on the cost of the treatment system.

° Activated carbon adsorption is an expensive treatment to install and operate. At present it does not appear economically feasible in the textile industry for most wastewater treatment and reuse applications, unless there is some critical and unusual factor, e.g., shortage of available water, restrictive limitation on allowable discharge volume or refractory constituents, etc. However, barring any such restrictive circumstances, there are insufficient savings to make it cost effective.

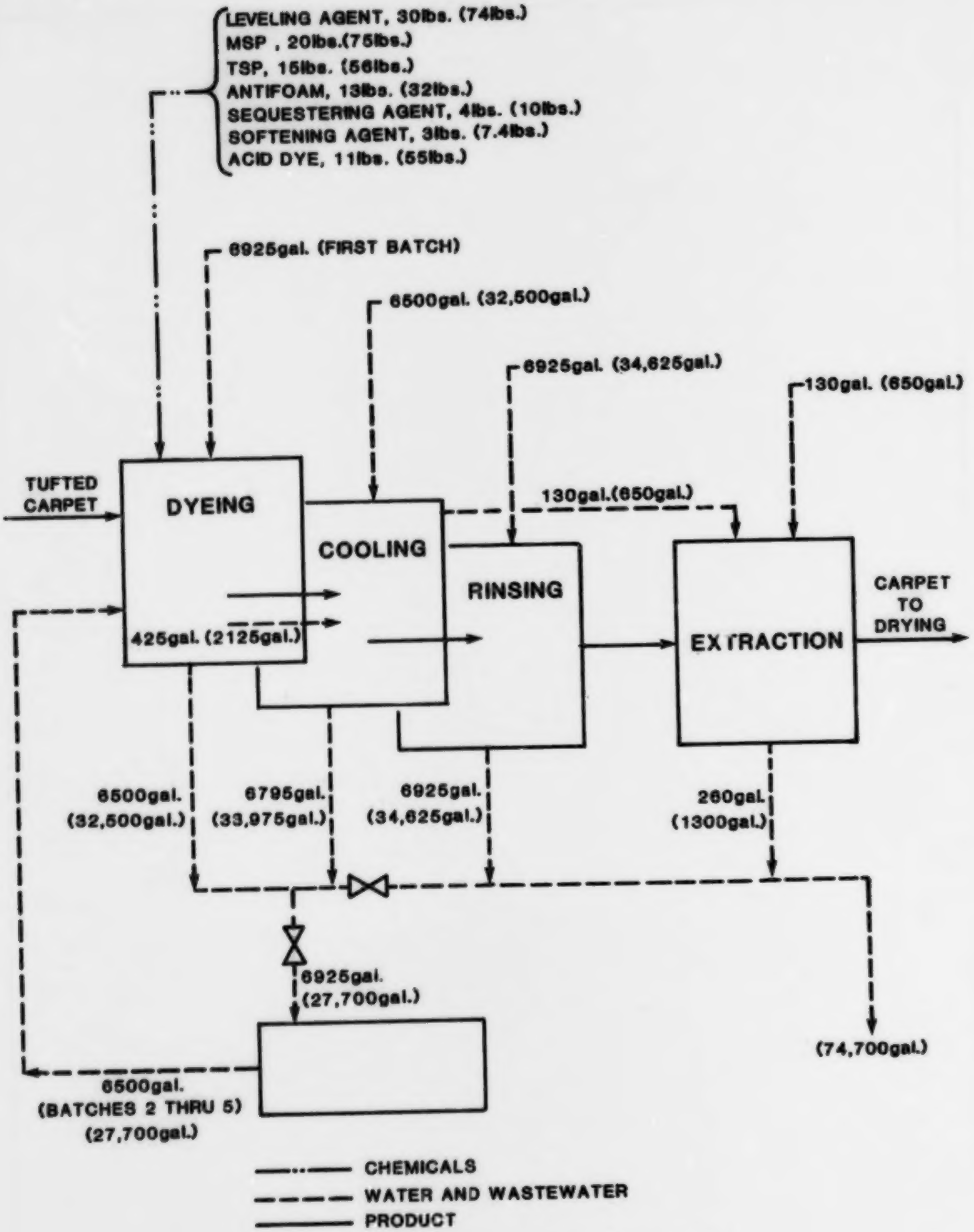
° Activated carbon is very effective at removing many constituents from wastewater. Hence, it often does not allow for chemical recovery and may be "overkill" in terms of recycle technology at a plant with only one major source of wastewater.

SECTION IV
RECONSTITUTION OF DYEBATH WASTEWATER

DESCRIPTION OF MANUFACTURING PROCESS AND PROPOSED MODIFICATION

A description of the dyeing operation at Mill C-2 was presented in Section I. Additional details and information on chemical usage, flows, and wastewater characteristics was provided in Section II. Accordingly, this information is not repeated here. Figure IV-1 can be compared with Figure II-1 to observe the differences between the existing dyeing operation and the revised dyeing operation employing reconstitution. Due to the small amount of disperse dyeing performed at this mill, it is probably worthwhile to reconstitute only acid dyebaths here.

Figure IV-1 shows that an idealized dyebeck of 6,925 gallons has been used in the analysis of dyebath reconstitution that follows. As has been previously noted, upon completion of dyeing the dyebath is cooled by displacement with city water. For reconstitution, it is assumed that the first 6,925 gallons discharged after dyeing from the beck by displacement followed by dumping is pumped to an elevated and insulated holding tank. At this point, the position of appropriate valves would be reversed so that the remainder of the cooling water and the rinse water could flow to the sewer. While the dyed carpet was being removed from the beck and the next one was being introduced, the reclaimed water in the storage tank would be analyzed spectrophotometrically to determine the appropriate amounts of dyes to add for the next batch. Auxiliary chemical makeup amounts could be calculated or a standard amount added to each batch based on operating experience. Once the appropriate quantities of dyes and chemicals had been added to the reclaimed water in the holding tank, appropriate valve(s) could be opened and the reconstituted dyebath used to dye the next batch of carpet. Each dye machine would have its own holding tank. In this section it is estimated that the dyebath water is reconstituted four times before being discharged, i.e., five batches of carpet are


LEVELING AGENT, 30lbs. (74lbs.)
MSP , 20lbs.(75lbs.)
TSP, 15lbs. (56lbs.)
ANTIFOAM, 13lbs. (32lbs.)
SEQUESTERING AGENT, 4lbs. (10lbs.)
SOFTENING AGENT, 3lbs. (7.4lbs.)
ACID DYE, 11lbs. (55lbs.)
6925gal. (FIRST BATCH)
6500gal. (32,500gal.)
6925gal. (34,625gal.)
130gal. (650gal.)
130gal.(650gal.)
TUFTED CARPET
DYEING
COOLING
RINSING
EXTRACTION
CARPET TO DRYING
425gal. (2125gal.)
6500gal. (32,500gal.)
6795gal. (33,975gal.)
6925gal. (34,625gal.)
260gal. (1300gal.)
6925gal. (27,700gal.)
(74,700gal.)
6500gal. (BATCHES 2 THRU 5) (27,700gal.)
CHEMICALS
WATER AND WASTEWATER
PRODUCT

NUMBERS IN PARENTHESES ARE FOR 5 CYCLES

FIGURE IV-1. REVISED DYEING CYCLE EMPLOYING RECONSTITUTION

dyed per reconstitution series. As much as possible, each series should go from light to dark colors as the series progresses.

TECHNICAL FEASIBILITY AND DESIGN CRITERIA

Literature and Previous Applications

A significant amount of research into the feasibility and technical aspects of dyebath reconstitution has been performed by the School of Textile Engineering at the Georgia Institute of Technology (Georgia Tech). A fair amount of this research has focused on reuse of exhausted acid dyebaths used to dye nylon carpets. The results of these bench- and pilot-scale investigations indicate that commercially acceptable carpet dyeings can be achieved with reconstituted dyebaths. A more detailed discussion of dyebath reconstitution research and applications is found in Volume 1.

Bench Scale Results

No bench scale tests of dyebath reconstitution have been performed at this mill. Company personnel are divided in their opinions as to the technical feasibility of reconstitution here.

Mill C-2 has high standards of quality that every carpet dyed here must meet. As mentioned earlier, adds are the rule, rather than the exception, in order to get accurate color matches of carpet to standards. Mill personnel note that although most dyebaths normally employ a red, a blue, and a yellow acid dye (i.e. the primary colors) to achieve a desired carpet color, only a specific one of a dozen or more common dye shades of each color can be used to obtain the exact dyeing result required. Thus, although only three colors are used, the combinations of dyes used (exclusive of relative quantities) number in the hundreds. For this reason some feel that reconstitution is not feasible at this mill.

Others within this company feel that appropriate dyebaths for most carpets dyed at this mill can be prepared from a very small combination of dyes (again exclusive of relative quantities). It is possible, they say, to use a "pure red" dye, a "pure blue" dye, and a "pure yellow" dye to achieve any color desired.

At some point, bench- or pilot-scale testing will be required to resolve this question satisfactorily.

Technical Design Criteria

In the absence of previous test results at this mill, all further evaluations of dyebath reconstitution are based on a reconstitution series consisting of five dyeings per series. This number is chosen based on published information on the subject in two Georgia Tech reports.

Potential locations for the reconstitution holding tanks at this mill are shown in Figure IV-2. Piping in place of or in addition to the open "channels" under the dyehouse floor, as well as lint screens and a pump, would be required to transport exhausted dyebaths to the holding tanks. Insulated and elevated holding tanks will enable retention of more heat value and eliminate the need for a return pump. Return piping and hardware will be necessary.

A spectrophotometer will be required to enable analysis of the exhausted dyebath and permit proper formulation of the succeeding dyebath.

ECONOMIC FEASIBILITY

Cost savings are realized in the areas of water use, wastewater discharge, energy savings, and auxiliary chemical use. In addition to capital costs, additional operating costs will be encountered for dyebath pumping.

Table IV-1 presents an analysis of the economics of dyebath reconstitution at this mill. The basis of these costs and savings is as follows:

- water supply at \$0.45/1000 gallons.
- sewer use charges of \$0.34/1000 gallons.
- auxiliary (dyeing) chemical costs of \$0.0764/sq yd of carpet.
- 51% savings in auxiliary chemicals (exc. MSP and TSP) per series; 25% savings of MSP and TSP.
- energy costs of \$3.07/1000 lb steam.
- bath used for dyeing 5 batches of carpet before being replaced.

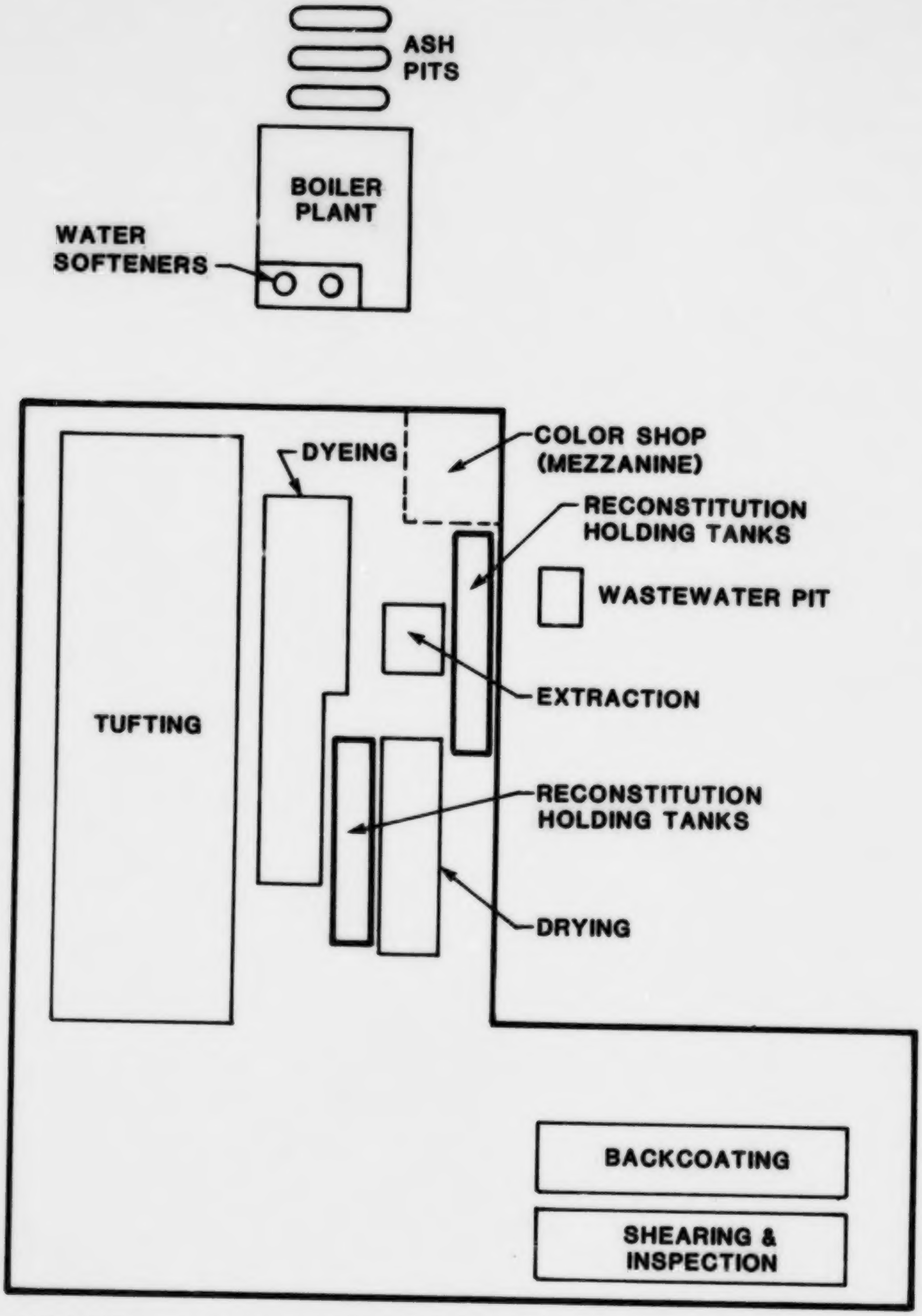

ASH PITS
BOILER PLANT
WATER SOFTENERS
DYEING
COLOR SHOP (MEZZANINE)
RECONSTITUTION HOLDING TANKS
WASTEWATER PIT
EXTRACTION
TUFTING
RECONSTITUTION HOLDING TANKS
DRYING
BACKCOATING
SHEARING & INSPECTION

FIGURE IV-2. POTENTIAL RECONSTITUTION HOLDING TANK LOCATIONS

TABLE IV-1

ECONOMICS

DYEBATH RECONSTITUTION*

Annual Operation and Maintenance Costs

Pumping to Elevated Storage Tanks		$ 55
Other Operation and Maintenance Costs		2,285
	Total	$ 2,340

Annual Savings

Water Supply		$ 1,870
Sewer Use Charges		1,410
Auxiliary Chemicals		15,856
Energy		1,945
	Total	$21,081

Capital Costs

Holding Tank		$12,000
Pump		3,800
Piping, Valves		1,900
Spectrophotometer		4,400
Lint Screen, Other Contingencies (at 15%)		3,300
Engineering (at 15%)		3,300
	Total	$28,700

Payback

Payback is estimated at approximately 1½ years.

* Assumes 1 beck, 6,500 gallons used for cooling per batch.

- 6,925 gallons of water returned to dyebath from holding tank at 120°F.
- average energy savings per reconstituted bath is 1056 lb steam.
- 6,500 gallons of water are used to cool dyebath by displacement.
- twelve dyebath drops are reconstituted per machine per week.
- operation and maintenance costs, except pumping, taken as 5 percent of capital costs.
- mill operates 50 weeks per year.

The analysis is conducted for an "average" dyebeck, i.e. 6925 gallon capacity. It must be realized that the actual dyebecks at this mill are all slightly smaller or larger than this idealized model. In addition, although this analysis is prepared for reconstitution at only one beck, it is likely that if reconstitution were feasible here, a number of becks would be appropriately modified.

An economic evaluation of the effect of employing 10 of the 13 becks at this mill for reconstitution is presented in Table IV-2. All other bases listed above remain the same with one exception: it is assumed that only 2,035 gallons of water are used for cooling the dyebath (see Section V), and as a result, auxiliary chemicals savings (except MSP and TSP) are 62 percent per series; MSP and TSP savings are 31 percent per series. (No credit is given to reconstitution for water savings in reducing cooling water from 6,500 gallons/batch to 2,035 gallons/batch.)

As seen in Tables IV-1 and IV-2, the payback period is estimated to range from approximately 1 to 1½ years.

ENVIRONMENTAL BENEFITS

The environmental benefits due to institution of reconstitution at Mill C-2 are dependent upon the number of dyebecks employed for reconstitution. For each dyebeck at which reconstitution regularly occurs, water use and wastewater discharge will be reduced by 83,100 gallons per week. Dyebath dumps appear to contribute at least

TABLE IV-2

ECONOMICS

DYEBATH RECONSTITUTION*

Annual Operation and Maintenance Costs

Pumping to Elevated Storage Tanks	$ 550
Other Operation and Maintenance Costs	22,850
Total	$ 23,400

Annual Savings

Water Supply	$ 18,700
Sewer Use Charges	14,100
Auxiliary Chemicals	193,180
Energy	19,450
Total	$245,430

Capital Costs

Holding Tanks (10)	$120,000
Pumps (10)	38,000
Piping, Valves	19,000
Spectrophotometers (2)	8,800
Lint Screen, Other Contingencies (at 5%)	27,900
Engineering (at 15%)	27,900
Total	$241,600

Payback

Payback is estimated at approximately 1.1 years.

* Assumes 10 becks, 2,035 gallons used for cooling per batch.

two-thirds of the total plant BOD_5 and COD discharge. Thus each dyebeck is responsible for approximately 5 percent of the total daily mill discharge of these pollutants. Assuming a 50 percent reduction in the amount of BOD and COD discharged from each beck where reconstitution is practiced gives a daily BOD_5 reduction of 62 lb/beck and a daily COD reduction of 147 lb/beck. Steam requirements for each dyebeck employing reconstitution will be reduced by 12,700 lbs per week. These steam savings will reduce the load on the boilers, thereby reducing air pollutant emissions and resulting in a secondary environmental benefit.

CONCLUSIONS

- Dyebath reconstitution has been shown to be feasible in acid dyeing of nylon carpet on bench- and pilot-scale investigations.
- Significant environmental benefits result from the institution of dyebath reconstitution.
- With a payback period of 1 to 2 years, the economics of reconstitution at this mill appear favorable.
- The feasibility of performing most dyeing at this mill with three to six different dyestuffs needs to be determined.
- If dyeing with a small number of dyestuffs is possible at this mill, pilot-scale testing should be performed at the mill to determine the effect, if any, of reconstitution on product quality, and to refine projected auxiliary chemical savings.

SECTION V

COOLING WATER REQUIREMENTS

DESCRIPTION OF MANUFACTURING PROCESS AND PROPOSED MODIFICATION

Mill C-2 uses city water to cool and displace dyebath wastewater prior to rinsing. As noted in Section I, the bath needs to be cooled only to 150°F prior to being dumped and the dyebeck refilled with cold (53°F) water. However, measurements during the sampling period showed the 178°F (avg) dyebath being cooled to 114°F (avg) with 68°F city water.

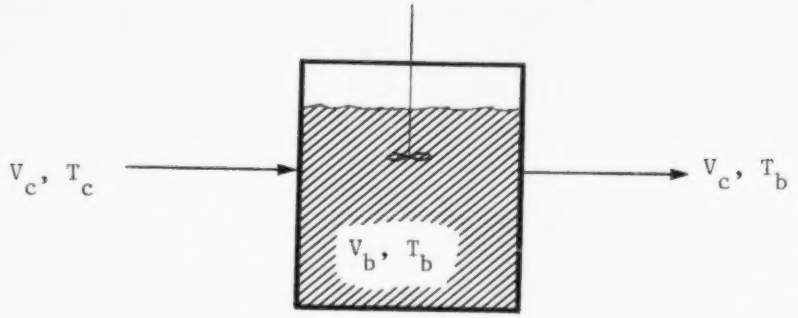
A complete-mix mathematical model (shown in Figure V-1) was used to calculate the water needed for cooling. Table V-1 presents the theoretical volumes of cooling water (based on this model) used to achieve the degree of cooling noted in six actual dyeings monitored during the field investigation. It can be seen in Table V-1 that an average of 6,500 gallons of water is used per batch for cooling the dyebeck contents to 114°F prior to the rinse operation. However, using the model and calculating the amount of 68°F water theoretically required to reduce the temperature of 6,925 gallons of dyebath from 178°F to only 150°F, gives a volume of 2,035 gallons cooling water per batch. Thus, overcooling of the dyebeck contents is consuming an estimated 4,465 gallons of water per batch.

TECHNICAL FEASIBILITY AND DESIGN CRITERIA

The mill clearly has the ability to monitor the temperature of the dyebath and control the amount of water used for cooling. No physical modifications are required to implement dyebath dumps consistently at 150°F. A change in operating procedures in the dyehouse or modifications to the program controlling the dyeing cycle should be sufficient.

ECONOMIC FEASIBILITY

Expenses associated with reducing the water used for dyebath cooling are minimal or nil. Water savings per batch is 4,465 gallons. Based on 211 batches per week, and operation 50 weeks per year, annual water savings are projected to be 47.1 million gallons. This results in



Assumptions:
- Complete Mix
- Flow In = Flow Out
- No Heat Loss to Atmosphere
- V_b (Beck Volume) and T_c (Temperature of City Water) are Constants

$$\Delta V_c T_b - \Delta V_c T_c = -V_b \Delta T_b \qquad \text{(Equation 1)}$$

$$-\int_{V_f}^{0} \frac{dV_c}{V_b} = \int_{T_f}^{T_i} \frac{dT_b}{T_b - T_c} \qquad \text{(Equation 2)}$$

$$-\frac{1}{V_b} V_c \Big|_{V_f}^{0} = \ln(T_b - T_c) \Big|_{T_f}^{T_i} \qquad \text{(Equation 3)}$$

$$\frac{V_f}{V_b} = \ln(T_i - T_c) - \ln(T_f - T_c) \qquad \text{(Equation 4)}$$

$$V_f = V_b \ln \frac{T_i - T_c}{T_f - T_c} \qquad \text{(Equation 5)}$$

Where V_c = volume of cooling water added to cool beck
T_b = temperature of water in beck
T_i = initial temperature of dyebath
T_f = final temperature of dyebath
V_f = theoretical volume of city water used to cool the dyebath from T_i to T_f

FIGURE V-1

BECK COOLING WATER MODEL

TABLE V-1

VOLUME OF WATER USED FOR DYEBATH COOLING

Trial	Vb*	Tc*	Ti*	Tf*	Vf**
1	7,113	68	176	136	3,300
2	7,113	68	185	113	6,800
3	7,113	68	185	104	8,400
4	7,375	68	167	99	8,600
5	7,113	68	171	136	2,900
6	7,375	68	185	95	10,800
Avg.	--	68	178	114	--

Average Volume of City Water Used for Dyebath Cooling =

$$\frac{3{,}300}{7{,}113} + \frac{6{,}800}{7{,}113} + \frac{8{,}400}{7{,}113} + \frac{8{,}600}{7{,}375} + \frac{2{,}950}{7{,}113} + \frac{10{,}800}{7{,}375} \div 6 \times 6{,}925 \text{ gal/batch}^{***}$$

$$= 6{,}500 \text{ gal/batch}$$

* Vb, Vf in gallons; Tc, Ti, Tf given in °F

** Vf calculated from Equation 5

*** 6,925 gallons is the average dyebeck volume at this mill a reduction in water use costs of $21,195 per year and sewer use charges of $16,014 per year. Additional minor savings are accrued since the mill will soften and pump less water.

ENVIRONMENTAL BENEFITS

Conservation of water used to cool the dyebath as described above will reduce the typical weekday water use from 1,143,000 gpd to 938,000 gpd. Wastewater discharge will fall to an estimated 804,000 gpd from the present 1,009,000 gpd. However pollutant loadings will remain unchanged and pollutant concentrations in the discharge will increase somewhat. Energy savings, although small, will be realized due to slightly lower pump operating costs.

CONCLUSIONS

- The mill is currently using and discharging excessive quantities of water due to poor control of the dyebath cooling procedure.
- Savings of nearly $40,000 annually are available with no additional capital investment.
- Significant reductions in the water used for dyebath cooling will affect the economics of the chlorine oxidation and activated carbon technology alternatives described in earlier sections. The economics of dyebath reconstitution will be unaffected.

SECTION VI

NONCONTACT COOLING OF DYEBATH WATER

DESCRIPTION OF MANUFACTURING PROCESS AND PROPOSED MODIFICATION

As has been noted previously, Mill C-2 uses city water to cool and displace dyebath wastewater after dyeing has been satisfactorily completed. An alternative to cooling the dyebath by displacement would be heat transfer using cooling coils. Cold water would pass through coils within the beck. In so doing, the noncontact cooling water would be heated and could be stored for dyebath makeup water, while the dyebath would be cooled.

TECHNICAL FEASIBILITY AND DESIGN CRITERIA

Noncontact cooling water and heat exchange arrangements are used in many industries and applications to achieve desired objectives such as product or waste cooling, product control, energy savings due to preheating of incoming water, and combinations of these. Cooling of the dyebath wastewater at this mill presents such an opportunity.

However, as discussed in Section V, excessive water is used at Mill C-2 to achieve dyebath cooling. Therefore, a necessary first step in evaluating dyebath cooling alternatives is to assume that the dyebath needs to be cooled only to 150°F. Other design criteria are listed below.

- dyebath is at 178°F prior to cooling
- city water is at 68°F
- volume of dyebath to be cooled is 6,925 gallons
- maximum time allowed for cooling is 30 minutes
- allowable cooling system pressure drop is 25 psi
- overall coefficient of heat transfer, U, taken as 80 BTU/hr sq ft °F
- 316 stainless steel serpentine double embossed panel coils, 16 gauge with a dimension of 143" x 43" to be used, providing 96.4 sq ft heat transfer surface area each

Within the above restrictions, 12 panels would be optimum as shown below.

Heat transfer surface area may be calculated using the following equation:

$$A = \frac{Q}{U \times \text{"LMTD"}} \qquad \text{(Equation 6)}$$

Where A = surface area available to transmit heat, sq ft.
Q = total quantity of heat added or extracted, BTU/hr
U = overall coefficient of heat transfer, BTU/(hr sq ft °F)
LMTD = logarithmic mean temperature difference, °F

To cool 6925 gallons of water 28°F in 30 minutes requires extraction of heat, Q, at the rate of 3,234,252 BTU/hr. If 2518 gallons are used for cooling inside the coils, then "LMTD" is found to be 35°F, and the exit temperature of the noncontact cooling water is 145°F. Substituting the values given above for Q, U, and "LMTD" into Equation 6 gives a surface area requirement of 1155 sq ft. Twelve panels provide 1157 sq ft of surface area. The flow through each panel is consequently 2518 gallons - 30 minutes - 12 panels = 7 gpm, and the resulting pressure drop as this water passes through the coil is 23 psi.

A bank of 12 panels would have the dimensions of approximately 12' x 4' x 2.5'. However, only 0.5' is available in the front portion of the becks to accomodate the bank. The becks will have to be modified to accommodate sufficient heat transfer surface area; one possibility would be to position the steam line, dye line and baffle farther from the front wall of the beck.

Some observations can be made regarding tradeoffs in developing an appropriate "in-beck" heat transfer arrangement. As the amount of time allowed for cooling is decreased, the term Q in Equation 6 becomes proportionally larger, and hence additional panels will be required for cooling. If flow through the panels is increased, the pressure drop also increases. For example doubling the flow through the panels from 7 gpm to 14 gpm results in a corresponding pressure drop increase from 23 psi to 85 psi. Conversely as flow through the panels decreases, the term "LMTD" in Equation 6 becomes smaller and hence required surface area becomes larger.

ECONOMIC FEASIBILITY

Table VI-1 presents information on the costs and annual savings of in-beck heat recovery. From an economic viewpoint, this water and energy reduction alternative is seen to be unattractive. There will be costs associated with cleaning and maintaining the plate coils, as well as operational costs associated with pumping. Even ignoring these costs that would cut into annual savings of $70,000, as well as any capital costs associated with modifying the dyebeck, it is seen that the relatively high capital costs for the heat transfer banks results in a long payback period.

ENVIRONMENTAL BENEFITS

Annual water savings of approximately 21 million gallons could be realized if the dyebaths are cooled using heat transfer coils. Energy savings equivalent to 17 million pounds of steam will also be realized. These water and energy savings assume that the 21 million gallons of 145°F water used in cooling the dyebecks can be used for boiler and dyebath makeup water. No reductions in pollutant discharge are obtained.

CONCLUSIONS

- The technology to implement in-situ cooling of dyebaths using noncontact cooling water is readily available. A number of manufacturers produce heat transfer coils in plate and other forms.
- Where large volumes of water must be cooled relatively quickly, the number of heat transfer panel coils required make the total capital costs for this technology relatively high.
- At this mill there is insufficient unused volume in the beck to allow for the necessary number of heat transfer panels required.

TABLE VI-1

ECONOMICS

IN-BECK HEAT TRANSFER (13 Becks)

Operation and Maintenance Costs

These costs were not developed. Operation and maintenance costs should be relatively low.

Annual Savings

Water Supply		$ 9,700
Sewer Use Charges		$ 7,300
Auxiliary Chemicals		$ 0
Energy		$53,000
	TOTAL	$70,000

Capital Costs

Twelve-panel heat transfer banks (13)		$528,000
Insulated Holding Tank (25,000 gallons)		30,000
Pipes and valves		25,000
Engineering and Contingencies (at 10%)		58,000
	TOTAL	$641,000

Payback

Payback of capital costs only, exclusive of interest or other costs, requires nearly ten years.

REFERENCES

1. Perkins, W. S., J. F. Judkins, Jr., and W. D. Perry. "Renovation of Dyebath Water by Chlorination or Ozonation," Textile Chemist and Colorist, Vol. 12, Nos. 8-10 (August-October, 1980), pp. 182-272.

2. Stark, M. M. and J. L. Rizzo. "Carbon Adsorption - Case Studies at Several Textile Plants," unpublished paper presented at Midwater Conference on Textile Wastewater and Air Pollution Control, January 23-25, 1974.

MILL SURVEY REPORT
MILL W-3
WOVEN FABRIC PREPARATION AND PRINTING

SUMMARY

Mill W-3, a woven fabric finishing mill, conducts various fabric finishing processes that have been investigated for the potential applicability of wastewater recycle/reuse technologies. Figure 1 illustrates the basic fabric finishing processes, summarizes the findings of this investigation, and identifies further research needs. Table 1 summarizes the projected savings, costs, and payback periods associated with wastewater recycle/reuse techniques considered at this mill.

The most promising recycle/reuse techniques at this mill are:

1. Evaporation of mercerizing wastewater for caustic recovery and water recycle (in-place);
2. Reuse of excess mercerizing wastewater in desizing;
3. Reuse of open width preparation range rinse water for open width scouring (complete countercurrent flow);
4. Upgrading in-place coagulation/flotation facilities and operating them to recycle print wastewater for equipment cleaning;
5. Flow reduction in the print and color shop; and
6. Direct water reuse and heat recovery in the soaphouse.

RECOMMENDATIONS

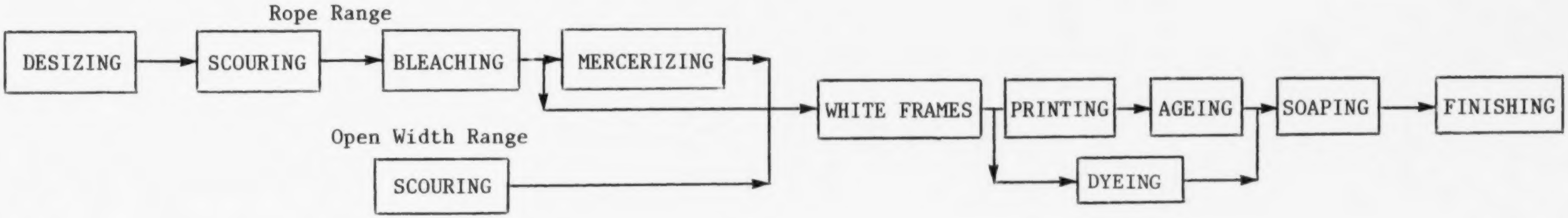
It is recommended that the following techniques and research needs be pursued for recycle/reuse of wastewater at this mill:

1. Bleachhouse Wastewater

a. Reuse of excess mercerizing wastewater at the desize washer and reuse of open width rinse water at the open width scour (complete counterflow) should be tested to determine effects on fabric quality and manufacturing processes.

b. A detailed investigation of piping, pumping, and storage requirements for direct reuse of mercerizing wastewater and open width rinse water should be conducted to establish capital costs more definitely.

c. Technical feasibility of ultrafiltration for size separation/recovery should be investigated in more detail. In particular, more research is needed on the feasibility of segregating PVA-sized


Rope Range
DESIZING
SCOURING
BLEACHING
MERCERIZING
Open Width Range
SCOURING
WHITE FRAMES
PRINTING
AGEING
DYEING
SOAPING
FINISHING

Techniques Evaluated	Feasibility		Data Needs
	Technical	Economic	
Bleachhouse Wastewater			
Direct Reuse Measures (Mercerizing to Desizing; Open Width Rinse to Open Width Scour)	Feasible	Promising	Effect on Processing and Fabric Quality
Ultrafiltration	Questionable	Questionable	Segregation of PVA-Sized Fabrics Desizing Efficiency Size Degradation Marketability of Recovered Size Effects of UF Permeate Recycle
Evaporation (In-place)	Feasible (In-place)	Promising	--
Print and Color Shop Wastewater			
Water Use Reduction Measures	Feasible	Promising	Current Water Use and Potential Reduction
Coagulation/Flotation (Upgrading)	Feasible	Promising	Effect on Equipment Cleaning
(New)	Feasible	Not Promising	--
Soaphouse Wastewater			
Direct Reuse and Heat Recovery	Feasible	Promising	Optimal Operating Conditions of Open Width Soapers

FIGURE 1

TABLE 1
SUMMARY OF ECONOMIC AND ENVIRONMENTAL BENEFITS OF VARIOUS RECYCLE SCHEMES

Recycle/Reuse Scheme	Annual Savings	Capital Cost	Payback (Years)	Flow Reduction gpd	Flow Reduction % Total	BOD Reduction lb/day	BOD Reduction % Total
Bleachhouse							
Evaporation							
Caustic Recovery (In-Place)	$325,000	$603,000	1.9	--	--	--	--
Ultrafiltration Size Separation	none to $630,000	$615,000 to $1,173,000	no payback to 1.9 years	222,000 to 282,000	15.9 to 20.1	1378 to 3033	16.4 to 36.1
Direct Reuse	$ 49,500	$ 24,000	0.5	174,000	12.4	--	--
Print and Color Shop							
Flow Reduction & Direct Reuse	$ 2,200	--	Immediate	63,000	4.5	--	--
Coagulation/Flotation (upgrading)	$ 49,000	$153,000	3.1	163,000	11.6	760	9.0
(new)	(20,000)	$376,000	no payback	163,000	11.6	3360	40.0
Soaphouse							
Direct Reuse and Heat Recovery	$135,000*	$683,000	5.0*	230,000	16.4	--	--

* Does not include value for increase in productivity due to new soaper.

fabrics from other sizes, the effects of water reduction/reuse on desizing efficiency, marketability of recovered size, and the effects of recycling the treated desizing wastewater on pollutant discharge, fabric quality, and manufacturing processes.

2. Print and Color Shop Wastewater

a. Monitoring of water use should be conducted, and water reduction measures should be implemented. Such measures include employee education and incentives for conservation, and arrangement and selection of equipment for improved housekeeping. Direct reuse of drum washer wastewater, box and brush wash water, and floor cleaning water should be investigated in more detail.

b. Coagulation/flotation facilities should be upgraded and operation improved to implement recycle of treated wastewater for equipment cleaning. The reuse of the treated wastewater should be tested to determine effects on equipment cleaning.

3. Soaphouse Wastewater

a. Reuse of open width soaper spray wastewater at the backgrey washer should be tested for any adverse effects on the backgrey washing process.

b. Optimal operating conditions for the open width soapers should be established to plan the details of direct reuse and heat recovery.

c. A detailed investigation of piping, pumping, and storage requirements for direct reuse and heat recovery should be conducted to establish capital costs more definitely.

TABLE OF CONTENTS

Page

Summary ii
Table of Contents vi

I. INTRODUCTION 1
  Facility Description 1
  Manufacturing Processes 1
  Overall Mass and Energy Balances 7
  Evaluation of Recycle/Reuse Technologies 19

II. BLEACHHOUSE WASTEWATER 20
  Description of Manufacturing Processes 20
  Description of Applicable Recycle/Reuse Methods 28
  Technical Feasibility 33
  Economic Feasibility 36
  Environmental Effects 37
  Conclusions 41
  Evaporation of Mercerizing Wastewater 42

III. PRINT & COLOR SHOP WASTEWATER 46
  Description of Manufacturing Processes and Wastewater Pretreatment 46
  Description of Applicable Recycle/Reuse Methods. 53
  Technical Feasibility 57
  Technical Design Criteria 60
  Economic Feasibility 61
  Environmental Effects 64
  Conclusions 64

TABLE OF CONTENTS (Continued)

Page

IV. SOAPHOUSE WASTEWATER 65
  Description of Manufacturing Processes 65
  Description of Applicable Recycle/Reuse Methods 72
  Technical Feasibility 75
  Technical Design Criteria 78
  Economic Feasibility 78
  Environmental Effects 80
  Conclusions 80

SECTION I
INTRODUCTION

FACILITY DESCRIPTION

Mill W-3 is engaged in the preparation, printing, and finishing of woven fabrics for wearing apparel. Total production during the field investigation averaged 300,000 yards per day, which is approximately equal to 85,000 pounds per day.

A large portion of the total production consists of all-cotton fabrics, and the remaining portion consists mainly of polyester/rayon blends. Polyester/cotton, rayon, and rayon/cotton blends are processed occasionally.

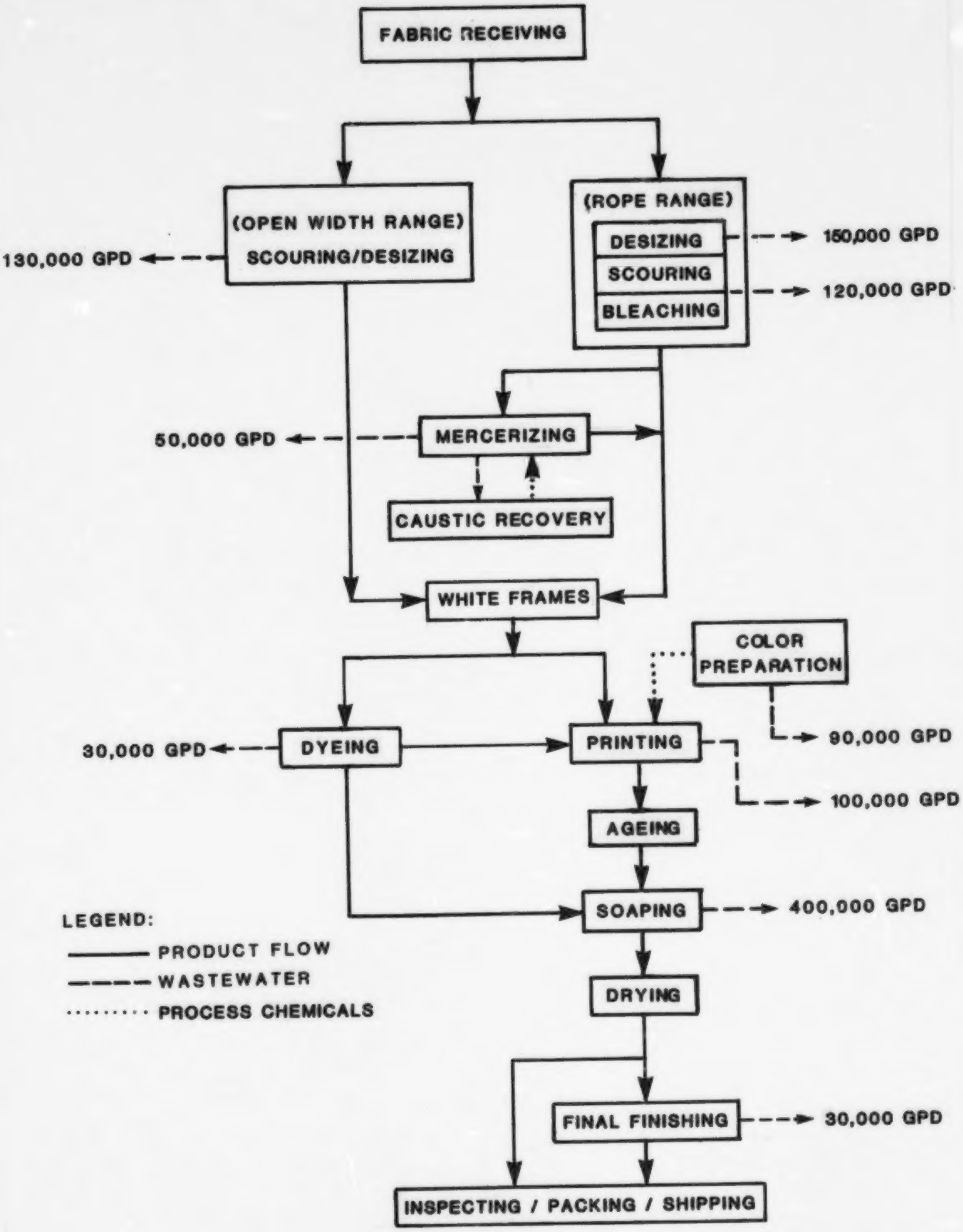
MANUFACTURING PROCESSES

The mill performs a variety of wet processes to prepare, print, and finish the incoming fabrics. These operations are illustrated on the schematic in Figure I-1 and include desizing, scouring, bleaching, mercerizing, dyeing, printing, ageing, soaping, and final finishing.

Desizing, Scouring, and Bleaching

The bleach house consists of an open-width range and a rope range. The open-width range is used primarily for desizing/scouring of polyester/rayon blends, thus processing a minor portion of the total mill production. The rope range is used for desizing, scouring, and bleaching of cotton or cotton blends, thus processing a major portion of total mill production.

The process sequence on the open-width range is a singer, padder, four counterflow wash compartments, a steamer, and finally five counterflow wash compartments. Detergent is used on this range to remove emulsifiers, lubricants and some size materials such as water-soluble PVA and starch from the polyester/rayon fabrics. The singer uses no water, while the padder sometimes discharges a small amount of warm water, about 4 to 5 gpm. Water enters the last compart-



FABRIC RECEIVING
(OPEN WIDTH RANGE)
SCOURING/DESIZING
130,000 GPD
(ROPE RANGE)
DESIZING
SCOURING
BLEACHING
150,000 GPD
120,000 GPD
MERCERIZING
50,000 GPD
CAUSTIC RECOVERY
WHITE FRAMES
COLOR PREPARATION
90,000 GPD
DYEING
30,000 GPD
PRINTING
100,000 GPD
AGEING
SOAPING
400,000 GPD
DRYING
FINAL FINISHING
30,000 GPD
INSPECTING / PACKING / SHIPPING
LEGEND:
PRODUCT FLOW
WASTEWATER
PROCESS CHEMICALS

FIGURE I-1
MANUFACTURING PROCESSES

ment of the first washer at a temperature of 175°F and a flow of approximately 20 gpm, and counterflows through the four compartments and is discharged. After bypassing the steamer, the fabric passes through a five-compartment unit for rinsing. Water enters the fifth compartment of this unit at 175°F and 65 gpm and counterflows through the remaining four compartments to the drain.

The process sequence on the rope range is much more extensive than that on the open-width range. A sequence of eleven machines is used to perform desizing, scouring, and bleaching. The first four machines in the range are used to effect desizing; after passing through a singer, the fabric goes sequentially to a desize saturator, a J box, and a desize washer (Washer 1). No water is discharged from the singer, saturator, or J box, although water and sodium bromite are added to the saturator. Approximately 75 gpm of 120°F to 140°F water are added to the desize washer, and frequently an additional 25 gpm of hot, evaporator condensate from the mercerizing caustic recovery unit is also fed to the washer. Thus, the discharge from this unit ranges from 75 gpm to 100 gpm. Size materials removed from the greige goods are primarily starch and PVA. Only very small amounts of CMC sized the greige goods are processed. Following desizing, the next four machines in this range are used for scouring. In order, the machines are a caustic saturator, a J box, and two washers (Washers 2 and 3). The final four machines in the range, a peroxide saturator, a J box, and Washers 4 & 5, are used for bleaching. Sodium hydroxide is added to the caustic saturator, while peroxide is added to the bleach saturator. There is no overflow or discharge from the saturators or J boxes. However, 90 gpm of 120°F to 140°F water enters Washer 5, counterflows to Washer 4, is pumped through a filter to Washer 3, and is discharged from Washer 2. The fabric, upon removal from Washer 5, is ready for mercerizing or printing.

These operations are illustrated and discussed further in the section on recycle/reuse technologies involved with the bleachhouse.

Mercerizing and Caustic Recovery

There are two identical mercerizing trains at the mill that processsed about 180,000 yards of cotton fabric per day during the field investigations. Each train consists of a padder, caustic saturator, counterflow chain and spray washers, a recuperator, and a three-compartment counterflow washer. Some water is added to the padder and purchased (50% NaOH) or recovered (35% NaOH) caustic is added to the saturator. Approximately 30-35 gpm of 120°F to 140°F water is fed countercurrent through the three compartments of the final washer; 15 gpm flows to the padder and is discharged to the drain while the remaining 15 gpm flows through the recuperator to the chain and spray washer. The discharge from the chain and spray washer is a weak (4 to 5% NaOH) solution that is pumped to the Zaremba caustic recovery unit along with 25% NaOH from the saturator overflow. The caustic saturators of the mercerizers experience a level rise in the system, thus causing the overflow.

As there are two mercerizing trains, approximately 30 gpm of washwater is pumped from the spray washers to the weak feed storage tanks associated with the caustic recovery system. From here the washwater flows into a double effect evaporator where the caustic strength is increased to 35% NaOH and piped to product storage. Wastewater (condensate) from the double effect evaporator is used in the rope range desize Washer 1. This Zaremba caustic recovery system has been in operation at the mill for ten years. The overall recovery rate for caustic is approximately 80 percent; in November, 1981, for example, the mill used 360,000 lbs of 100% caustic and recovered 304,000 lbs. Although the primary cost in caustic recovery is for steam, the overall savings through recovery of caustic are substantial.

This system is illustrated and discussed further in the section on recycle/reuse technologies involved with the bleachhouse.

Dyeing

Dyeing is performed on an "as needed" basis at the mill to supplement the printing operation. During the field investigations, production ranged from zero to 63,000 yards per day and averaged about 40,000 yards per day.

The type of dyeing is also quite variable, depending on the requirements of the fabrics. Fiber reactive and azoic dyes are used on cottons, and disperse dyes on polyester.

Since the processing here is so variable, this area is not included in any discussions of recycle/reuse technologies.

Printing

The printing operation is the heart of this mill, consisting of engraved roller printing on up to 14 machines. Roller printing requires the precise coordination of many moving parts to achieve a quality product. For each color being printed on a fabric, one engraved roller is required. Ten engraved rollers, and hence ten colors, are the maximum that can be used with a machine in a given run. Color is pumped from a color kettle to a color pan (tray). A furnishing roll (brush) partly submerged in the tray picks up color and transfers it to an engraved copper roll; a stationary doctor blade removes excess dye from the roll as it rotates immediately prior to the copper roll's contact with the fabric. The fabric is printed with the pattern on the engraved copper roll as it passes between this roll and a drive cylinder. A grey backing material is also pressed between these two rotating elements on the cylinder side of the printed fabric to absorb excess color and prevent contamination of the drive cylinder.

The color shop is the portion of the mill where various dyes and pigments are mixed and prepared for use in the printing machines. At some point in the future an automated color-mixing system may be instituted.

The primary use of water in the print shop is for equipment cleaning. Two large bays are available for washing brushes, blades, trays, and rollers. These items are removed from the print machines and taken to one of the two spray booths to be cleaned. A high pressure stream of water from a 1- or 2-inch hose is played on these removable print machine parts until all traces of color have been eliminated. Additional water is used in the print area for hosing down the print machines and cleaning the color pumps by pumping water through them whenever colors are changed. All these cleaning operations in the print shop area are performed manually; no cleaning equipment or machines are used. Each print machine has a drain underneath to collect wastewater from machine and pump cleaning. Water is used in the color shop primarily for hosing down mixers and for cleaning color tubs in a drum washer.

Water use, wastewater characteristics, and potential for recycle/reuse are discussed in further detail in subsequent sections.

Ageing and Soaping

A process called ageing is employed following printing to fix and develop the colors for increased fastness to washing and sunlight. The fabric is aged using neutral or acid steam or heat. Soapers are employed after ageing to wash out unfixed dyes and pastes. The mill has one rope soaper, one new open-width soaper, and one backgrey washer. Another new open-width soaper is due to be on-line shortly*. After passing through the soapers and dry cans, the fabric is packed in boxes.

The rope soaper* washes plain dye work and selected print work. It operated about 16 hours (two shifts) per day during the field investigation and processed about 120,000 yards per day. The rope soaper consists of four washers followed by dry cans; however, the fourth washer is frequently bypassed. Soap is added to Washers 1 and 2. Hot water at 120°F to 160°F is added to Washer 1 at about 10 gpm, Washer 2 at about 60 gpm, and Washer 3 at about 60 gpm. An additional 30 gpm of cold water is added to Washer 3. The unit is constructed to allow for counterflow from Washer 3 to Washer 2, but counterflow is usually not employed.

Each new open-width soaper consists of two spray boxes followed by five washers before the fabric reaches the dry cans. The mill is experimenting to identify the optimum mode of operation in terms of water use and temperatures. During the field investigation one soaper was in operation, processing about 180,000 yards per day.

The primary mode of operation (Mode 1) of the open-width soaper consists of adding 15 gpm of cold water through each of the two spray boxes and 25 gpm of hot water counterflowed from Washer 5 to Washer 1. This mode is employed about 80 percent of the time.

---

* Subsequent to the field investigation, the mill abandoned the rope soaper and replaced it with a second open-width soaper.

Mode 2, which has been used about 20 percent of the time, consists of adding 15 gpm of cold water through the spray boxes, 25 gpm of hot water counterflowed from Washer 5 to Washer 3, and 20 gpm of hot water counterflowed from Washer 2 to Washer 1. This has been used on fabrics that have appeared more difficult to wash because of greater amounts of excess color.

The backgrey washer is used to clean the fabric that passes between the printed fabric and drive cylinder in the roller printing operation prior to its reuse. The cloth passes through two washers and dry cans. Clean water at 120°F to 160°F enters Washer 2 at 20 to 50 gpm (average 25 gpm) and counterflows to Washer 1 prior to discharge. The water required for this operation need not be of as high quality as that in other processes since this fabric is used only to absorb dyes and pigments between the product cloth and printing machine cylinder.

This area is illustrated and discussed in more detail in the section on recyle/reuse technologies involved with the soaphouse.

Final Finishing

The finishing room applies special finishes to some of the fabric after soaping and drying. The finishing generally requires a small quantity of high quality water to apply finishes such as lustre, embossing, wrinkle-resistance, shrinkage control, and others. A relatively small quantity of water is used for equipment cleaning.

Observations and discussions with mill personnel revealed that this area of the mill does not have a significant potential for wastewater recycle/reuse, so it will not be discussed in further detail.

OVERALL MASS AND ENERGY BALANCES

Water Use and Characteristics

Total water use at the mill averages about 1,500,000 gpd. The major areas of water use are the bleach house with its processes of desizing, scouring, and bleaching (406,000 gpd); mercerizers (100,000 gpd); dyeing (33,000 gpd); print and color shop (200,000 gpd); soapers and backgrey washer (440,000 gpd); and final finishing (33,000 gpd).

Minor uses are for boiler makeup and utilities, acid ager scrubbers, the print wastewater pretreatment system (belt press for DAF sludge dewatering), and sanitary and general maintenance. The overall water balance is illustrated on Figures I-2 and I-3. Most of the water comes from a mill pond, with the exception of sanitary water, which is purchased from the local municipal system. Some of the pond water is preheated through the mill's turbine condenser and subsequently stored for warm water uses. The mill also employs heat exchangers to further heat incoming water with the heat of hot wastewater discharges from the bleach house and mercerizers.

Table I-1 illustrates the quality of the incoming process water from the mill pond.

Wastewater Discharge and Characteristics

The major sources of wastewater discharge are the processes named as the major water users. Some losses are incurred due to water retention in the fabric after the bleach house and the soap house, evaporative losses, pipe leakage, and other housekeeping considerations. Suspected infiltration into the final effluent line makes up for some of these losses, so the average final effluent discharge is about 1,400,000 gpd. The wastewater balance is illustrated in Figures I-2 and I-3.

Hot wastewater from the bleach house and mercerizers flows through a heat exchanger before discharge to the mill's pretreatment system in order to heat incoming process water. Mill personnel state that typically the bleachhouse wastewater enters at 152°F and heats the incoming fresh water (already preheated in the mill's turbine condensers) from 110°F to 132°F. The bleachhouse wastewater discharges at about 132°F.

A portion of the mercerizer wastewater is pumped to a Zaremba double-effect evaporator for caustic recovery. Only about half the wastewater flows through chain and spray washers, as described earlier, in order to yield an adequate caustic concentration for the recovery process. The operation and performance of this system are described in more detail in the section on recycle/reuse technologies. Wastewater samples were collected and analyzed from the major manufacturing

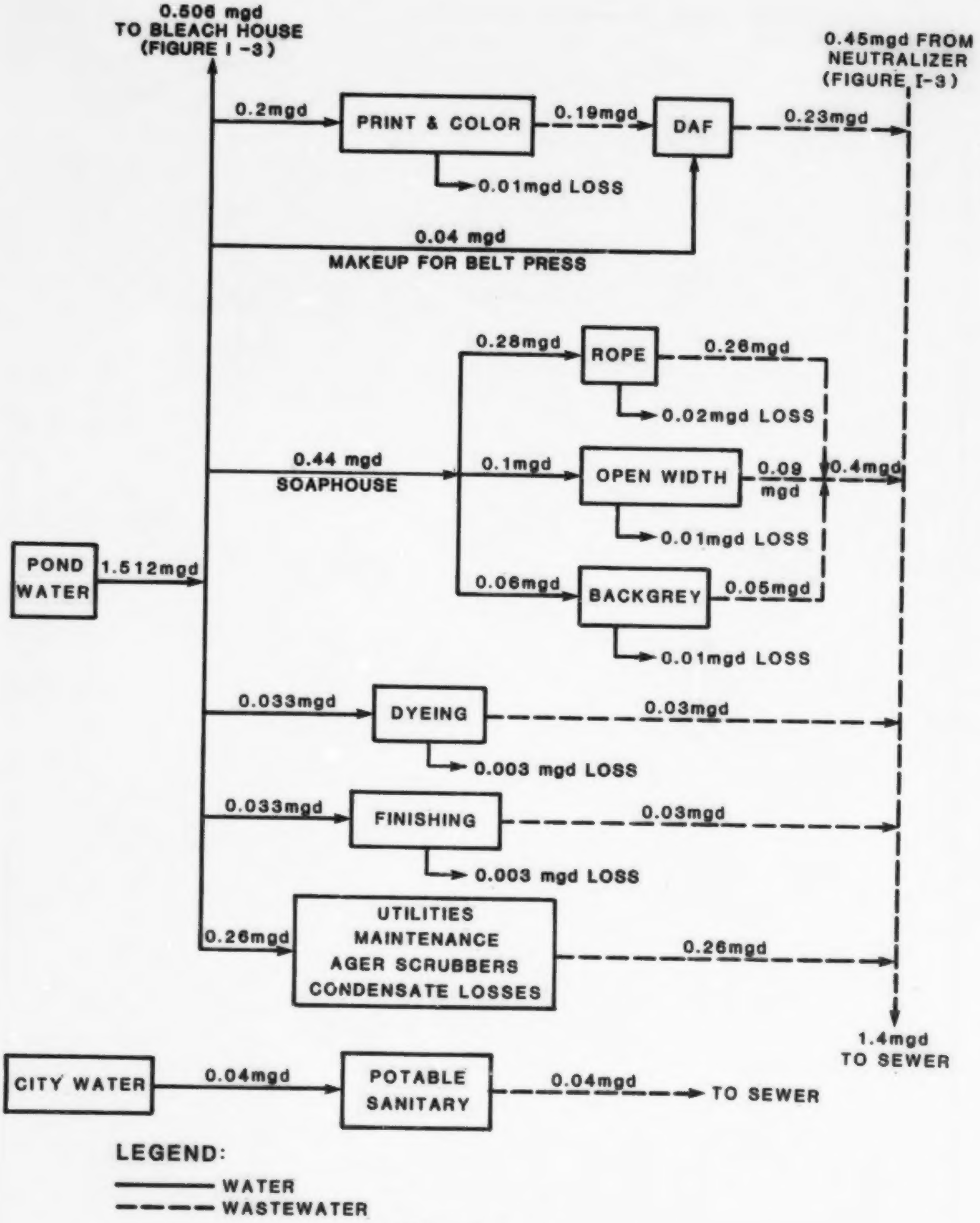

0.506 mgd
TO BLEACH HOUSE
(FIGURE I -3)
0.45mgd FROM
NEUTRALIZER
(FIGURE I-3)
0.2mgd
PRINT & COLOR
0.19mgd
DAF
0.23mgd
0.01mgd LOSS
0.04 mgd
MAKEUP FOR BELT PRESS
0.28mgd
ROPE
0.26mgd
0.02mgd LOSS
0.44 mgd
SOAPHOUSE
0.1mgd
OPEN WIDTH
0.09
mgd
0.4mgd
0.01mgd LOSS
POND
WATER
1.512mgd
0.06mgd
BACKGREY
0.05mgd
0.01mgd LOSS
0.033mgd
DYEING
0.03mgd
0.003 mgd LOSS
0.033mgd
FINISHING
0.03mgd
0.003 mgd LOSS
0.26mgd
UTILITIES
MAINTENANCE
AGER SCRUBBERS
CONDENSATE LOSSES
0.26mgd
1.4mgd
TO SEWER
CITY WATER
0.04mgd
POTABLE
SANITARY
0.04mgd
TO SEWER
LEGEND:
WATER
WASTEWATER

FIGURE I-2
WATER USE AND WASTEWATER DISCHARGE
PRINTING AND MISCELLANEOUS

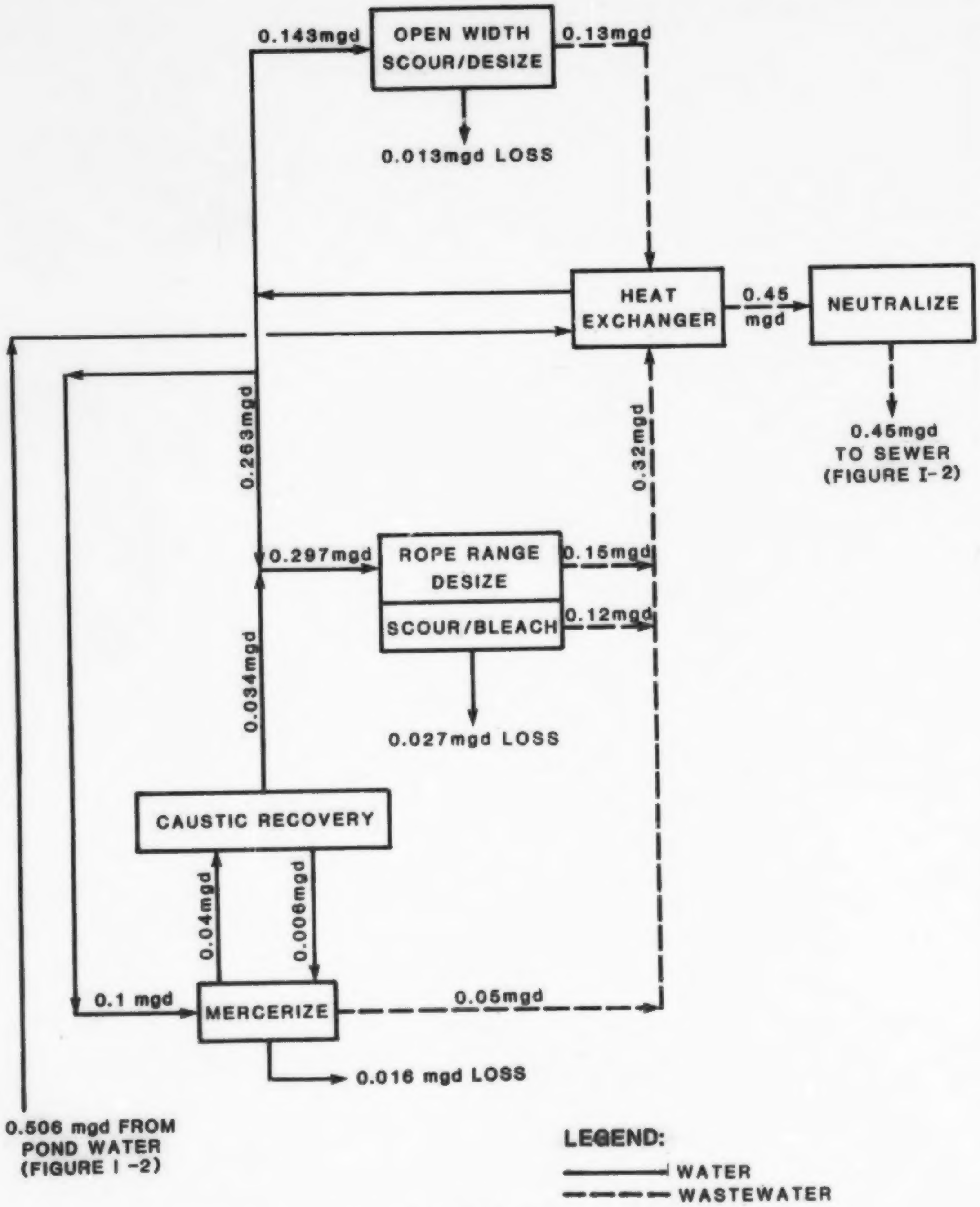

0.143mgd
OPEN WIDTH SCOUR/DESIZE
0.13mgd
0.013mgd LOSS
HEAT EXCHANGER
0.45 mgd
NEUTRALIZE
0.45mgd TO SEWER (FIGURE I-2)
0.263mgd
0.32mgd
0.297mgd
ROPE RANGE DESIZE
SCOUR/BLEACH
0.15mgd
0.12mgd
0.034mgd
0.027mgd LOSS
CAUSTIC RECOVERY
0.04mgd
0.006mgd
0.1 mgd
MERCERIZE
0.05mgd
0.016 mgd LOSS
0.506 mgd FROM POND WATER (FIGURE I -2)
LEGEND:
WATER
WASTEWATER

FIGURE I -3
WATER USE AND WASTEWATER DISCHARGE
BLEACHHOUSE

TABLE I-1
POND WATER

	Concentration, mg/l
Alkalinity (as $CaCO_3$)	10
BOD	--
COD	15
TDS	59
TSS	6
Chloride	11
Oil & Grease	--
Phenolics	<0.01
Turbidity (NTU)	0.55
Color (ADMI)	14
Hardness (as $CaCO_3$)	20
Sodium	17
Chromium	<0.1
Copper	<0.1
Iron	0.23
Manganese	<0.1
Zinc	<0.1
pH (SU)	7.8
Temperature (°F)	72

Source: Water sample taken May 18, 1982.

processes of desizing (rope range), scouring/bleaching (rope range), scouring/desizing (open width range), mercerizing, printing and color preparation, soaping, and of the mill's final effluent. The results for conventional and nonconventional textile pollutants are presented in Table I-2 and discussed below. Table I-3 presents pollutant loadings for the major wastewater streams. Table I-4 presents results for all parameters analyzed in the final effluent. Other wastewater constituents that affect recycle are discussed below under the appropriate manufacturing processes.

Wastewater Pretreatment

Discharge from the bleach house and mercerizers flows to a 0.6-million-gallon basin for neutralization with sulfuric acid. Sulfuric acid is added at a rate of 3,000 to 3,500 gallons per month. The neutralized wastewater joins other mill wastewater and is discharged to the municipal treatment system.

Discharge from the print and color shop is stored in a 0.6-million-gallon equalization basin and pumped subsequently to a dissolved air flotation (DAF) clarifier. Ferric chloride and polymer are added to coagulate the print and color wastewater and enable flotation of the solids. The float sludge is dewatered on a belt press, and the clarified effluent joins other mill wastewater and is discharged to the municipal treatment system.

Samples were collected and analyzed from the DAF effluent, and results are presented in the discussion of DAF operation and performance in the section on recycle/reuse of print wastewater.

Energy Use and Types

The major sources for energy at the mill are fuel oil, natural gas, and electricity. Fuel oil is used for space and water heating and cogeneration of electricity; natural gas is used for operation of dryers and curers; and electricity is used for lighting and machinery operation throughout the mill. Overall energy use at the mill in 1981 was $737,188 \times 10^6$ BTU per year; approximately 30 percent of all the energy is used for fabric preparation (desizing, scouring, bleaching, mercerizing). This results in an energy use of 36,000 BTU/lb of fabric, and the average cost is \$5.14 per 10^6 BTU.

TABLE I-2
WASTEWATER CHARACTERISTICS
BLEACHHOUSE

		Concentration (mg/l)				
Wastewater Source	Date	BOD	COD	TSS	Phenolics	pH (SU)
Rope Range						
Desize	5/19/82	2,850	5,040	830	0.14	-
	5/20/82	3,500	5,600	790	0.06	6.2
	5/21/82	1,520	3,450	490	< 0.01	6.8
Avg.		2,620	4,700	700	0.07	-
Scour/Bleach	5/19/82	2,450	5,600	340	0.032	-
	5/20/82	2,750	6,630	630	0.049	11.5
	5/21/82	2,120	5,400	270	0.13	11.7
Avg.		2,440	5,880	410	0.07	-
Open Width Prep. Range						
Desize/Scour	5/19/82	6,000	12,200	5,200	< 0.01	-
	5/20/82	2,400	8,900	1,110	0.032	6.2
	5/21/82	3,000	9,520	250	0.021	7.2
Avg.		3,800	10,210	2,190	0.021	-
Rinse	5/19/82	180	300	66	< 0.01	-
	5/20/82	72	32	20	< 0.01	6.4
	5/21/82	120	160	10	< 0.01	6.5
Avg.		124	164	32	< 0.01	-
Mercerizer						
Rinse	5/18/82	63	42	23	0.009	10.4
	5/19/82	22	54	10	< 0.01	11.0
	5/20/82	44	62	30	0.0015	11.4
Avg.		43	53	21	0.007	-

TABLE I-2 (continued)
WASTEWATER CHARACTERISTICS
SOAPHOUSE

Wastewater Source	Date	Concentration (mg/l)				
		BOD	COD	TSS	Phenolics	pH (SU)
Rope Soaper* Wash 1	5/19/82	180	600	25	0.049	9.3
Wash 2	5/19/82	36	42	8	<0.01	8.5
Open Width Soaper						
Mode 1 - Spray 1	5/18/82	1,650	3,870	74	0.37	5.9
	5/19/82	1,450	3,280	52	0.24	5.8
Avg.		1,550	3,580	63	0.30	-
Spray 2	5/18/82	950	2,220	55	0.21	5.9
	5/19/82	550	1,550	56	0.16	5.9
Avg.		750	1,890	56	0.19	-
Wash 1	5/18/82	153	2,180	130	1.76	6.3
	5/19/82	700	1,780	80	0.53	6.1
Avg.		430	1,980	105	1.15	-
Mode 2 - Spray 1	5/19/82	440	1,710	46	0.18	-
Spray 2	5/19/82	220	600	40	0.12	-
Wash 1	5/19/82	560	1,450	64	0.41	-
Wash 3	5/19/82	500	1,590	240	0.28	-
Backgrey Washer	5/18/82	500	2,310	190	1.93	9.0
	5/19/82	1,000	1,470	280	8.56	9.6
	5/20/82	480	2,300	70	13.26	9.4
Avg.		660	2,030	180	7.92	-

* Rope soaper was abandoned subsequent to the field investigations, and replaced by a new open width soaper.

TABLE I-2 (continued)
WASTEWATER CHARACTERISTICS
OTHER WASTEWATERS

		Concentration (mg/l)				
Wastewater Source	Date	BOD	COD	TSS	Phenolics	pH (SU)
Raw Print Wastewater	5/18/82	2,700	6,590	620	3.83	-
	5/19/82	3,400	10,300	540	9.33	-
	5/20/82	1,050	3,200	310	3.15	10.7
Avg.		2,380	6,700	490	5.44	-
DAF Treated Effluent	5/18/82	550	1,080	220	1.54	-
	5/19/82	680	2,300	350	1.38	5.1
	5/20/82	1,000	2,200	992	1.87	5.1
Avg.		740	1,860	520	1.60	-
Final Effluent	5/18/82	500	1,970	390	0.43	-
	5/19/82	600	1,500	350	0.27	-
	5/20/82	1,050	1,650	550	0.58	9.3
Avg.		720	1,710	430	0.43	-

Source: Wastewater samples taken May 17 to 21, 1982.

TABLE I-3

POLLUTANT LOADINGS

Source		Flow#		BOD		COD		TSS		Phenolics	
		mgd	% Total	lb/day	% Total	lb/day	% Total	lb/day	% Total	lb/day	% Total
Bleachhouse											
Rope Range Desize		0.15	10.7	3,278	39.0	5,880	29.5	876	17.4	0.09	1.8
Rope Range - Scour/ Bleach		0.12	8.6	2,442	29.0	5,885	29.5	410	8.2	0.07	1.4
Open-Width Scour		0.032	2.3	1,014	12.1	2,725	13.6	584	11.6	0.006	0.1
Open-Width Rinse		0.098	7.0	101	1.2	134	0.7	26	0.5	-	-
Mercerizer Rinse		0.05	3.6	18	0.2	22	0.1	9	0.2	0.003	0.1
Total Bleachhouse		0.45	32.1	6,853	81.5	14,646	73.3	1,905	37.9	0.169	3.4
Soaphouse											
Rope Soaper*-	Wash 1	0.016	1.1	24	0.3	80	0.4	3.3	0.1	0.007	0.1
	Wash 2	0.098	7.0	29	0.3	34	0.2	6.5	0.1	-	-
	Wash 3	0.146	10.4	-	-	-	-	-	-	-	-
	Total	0.26	18.6	53	0.6	114	0.6	9.8	0.2	0.007	0.1
Open-Width Mode 1	Spray 1	0.020	1.4	259	3.1	597	3.0	10.5	0.2	0.05	1.0
	Spray 2	0.020	1.4	125	1.5	315	1.6	9.3	0.2	0.03	0.6
	Wash 1	0.032	2.3	115	1.4	528	2.6	28	0.6	0.31	6.2
	Total	0.072	5.1	499	5.9	1,440	7.2	47.8	1.0	0.39	7.8
Mode 2	Spray 1	0.0036	0.3	13	0.2	51	0.3	1.4	0.0	0.005	0.1
	Spray 2	0.0036	0.3	7	0.1	18	0.1	1.2	0.0	0.004	0.1
	Wash 1	0.0048	0.3	22	0.3	58	0.3	2.6	0.1	0.016	0.3
	Wash 3	0.006	0.4	25	0.3	80	0.4	12.0	0.2	0.014	0.3
	Total	0.018	1.3	67	0.8	207	1.0	17.2	0.3	0.039	0.8

* Rope Soaper was abandoned subsequent to the field investigations and replaced by a new open width soaper.

TABLE I-3 (Continued)

POLLUTANT LOADINGS

Source	Flow#		BOD		COD		TSS		Phenolics	
	mgd	% Total	lb/day	% Total	lb/day	% Total	lb/day	% Total	lb/day	% Total
Backgrey Washer	0.05	3.6	275	3.3	847	4.2	75	1.5	3.3	65.7
Total Soaphouse	0.4	28.6	893	10.6	2,608	13.1	150	3.0	3.74	74.5
Other Wastewater										
Raw Print Wastewater (not added to total)	0.19	-	3,771	-	10,617	-	776	-	8.6	-
DAF Treated Effluent	0.19	13.6	1,173	14.0	2,947	14.8	824	16.4	2.54	50.6
+ Belt Press Makeup	0.04	2.9	-	-	-	-	-	-	-	-
Add DAF + Bleachhouse + Soaphouse	1.08	77.1	8,920	-	20,201	-	2,879	-	6.45	-
Miscellaneous + Dyeing + Finishing*	0.32	22.9	(513)	-	(235)	-	2,142**	-	(1.43)***	-
Final Effluent	1.4	100	8,407	100	19,966	100	5,021	100	5.02	100

* Unaccounted flow and pollutant loadings allocated here.

** Perhaps due to precipitation reactions in final effluent line.

*** Some phenolic compounds may volatilize in atmosphere before final discharge to sewer.

# Flow data for the most part were estimated based on operator comments and overall flow balance discussed with mill personnel. Flow meters present on the DAF effluent and final effluent were also used in obtaining overall balance.

TABLE I-4

FINAL EFFLUENT

	Concentration, mg/l		
Alkalinity (as $CaCO_3$)	870	1,220	850
BOD	500	600	1,050
COD	1,970	1,500	1,650
TDS	1,640	3,790	3,780
TSS	390	350	550
Chloride	190	170	170
Oil & Grease	210	120	210
Phenolics	0.43	0.27	0.58
Turbidity (NTU)	5.1	80	100
Color (ADMI)	1,200	1,100	1,570
Hardness (as $CaCO_3$)	97	40	40
Sodium	610	2,180	600
Chromium	3.6	1.8	1.6
Copper	1.2	0.43	0.56
Iron	82	15	21
Manganese	2.9	1.4	1.4
Zinc	0.33	0.35	0.19
pH (SU)	-	-	9.3
Temperature (°F)	102	102	109

Source: Wastewater samples taken May 17 to 21, 1982.

EVALUATION OF RECYCLE/REUSE TECHNOLOGIES

The areas at Mill W-3 that were selected for study of recycle/reuse methods are the following:

1. Bleachhouse Wastewater
    a. Flow reduction and direct reuse measures.
    b. Ultrafiltration for size separation and water recycle.
    c. Mercerizing waste - Evaporation for caustic recovery and water recycle.
2. Print & Color Shop Wastewater
    a. Flow reduction and direct reuse measures.
    b. Coagulation/flotation for water recycle.
3. Soaphouse Wastewater
    a. Flow reduction
    b. Direct reuse and heat recovery.

Each of these is considered in detail in the following sections.

SECTION II
BLEACHHOUSE WASTEWATER

DESCRIPTION OF MANUFACTURING PROCESSES

A major portion of the incoming fabrics to be finished at this mill consists of all-cotton or cotton blends that are desized, scoured, and bleached on the rope range in preparation for printing. A minor portion consists of polyester/rayon and other polyester blends that are desized and scoured on the open width preparation range. Most of the goods are sized with PVA, starch, or a combination of the two. The mill has little or no control over the amounts or types of size on the fabrics, because they are sent from greige mills around the nation and world.

The rope and open width preparation ranges are described in the introduction and are illustrated in Figures II-1 and II-2.

A major portion of the total production also is mercerized. These fabrics are primarily all cotton. The mercerizer is described in the introduction and is illustrated in Figure II-3, incorporated with the caustic recovery system.

Water and Chemical Use

Rope Range Desizing. The schematic diagram in Figure II-1 shows that about 165,000 gpd are used at the desize washer, which includes about 34,000 gpd of hot condensate from the caustic recovery multiple effect evaporator. The range processes about 60,000 pounds of fabric per day, resulting in an average water use of 2.75 gallons per lb of fabric for desizing. The resulting wastewater flow of 150,000 gpd is discharged at about 140°F with other bleachhouse wastewater to a heat exchanger before flowing to the bleachhouse neutralization basin and final discharge to the sewer.

The most important chemical added at the desize saturator is sodium bromite, which catalyzes a reaction to break down the starch size on the fabrics. This reaction proceeds in the J-box, which provides a range of detention times from 40 to 80 minutes.

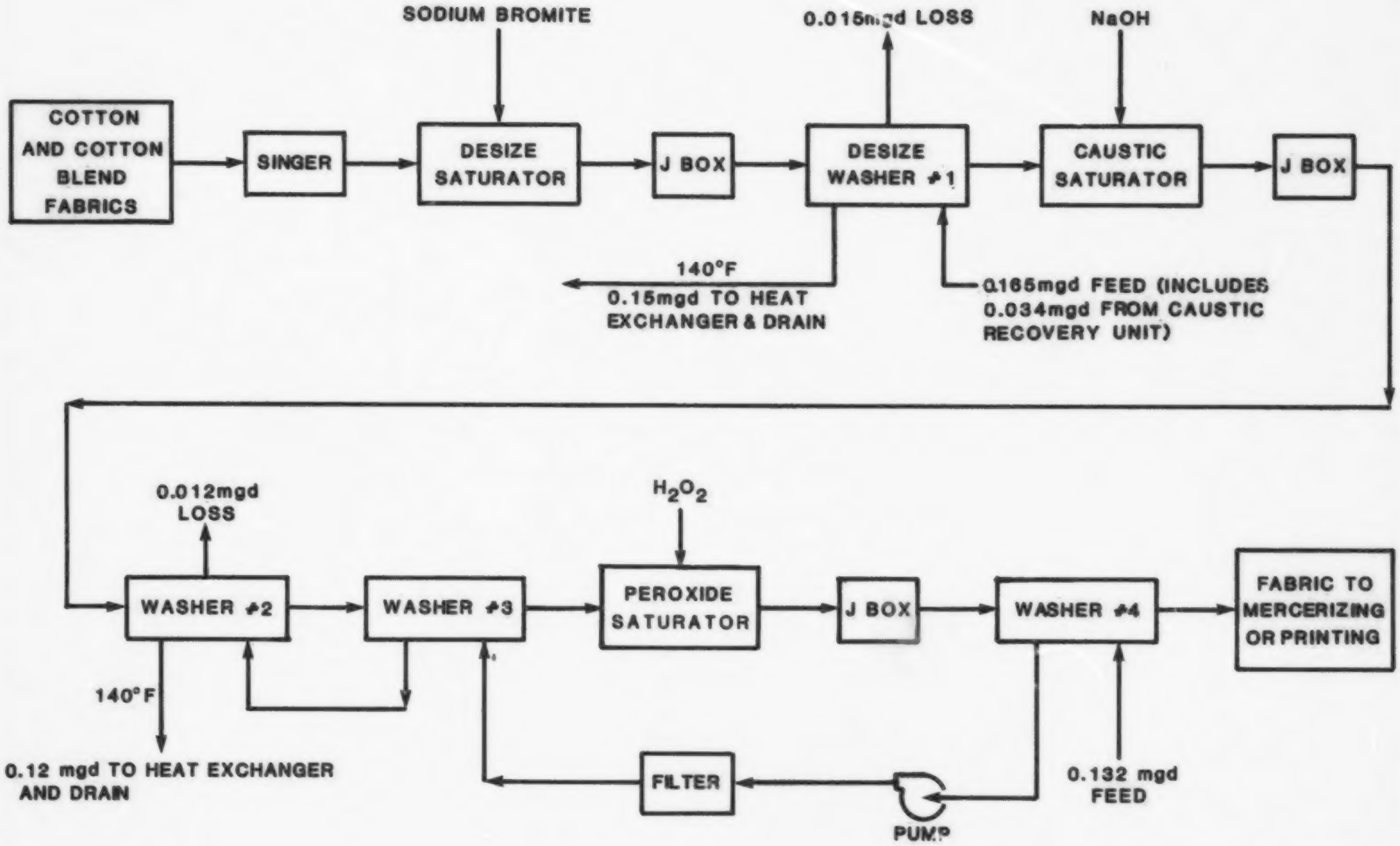

SODIUM BROMITE
0.015mgd LOSS
NaOH
COTTON AND COTTON BLEND FABRICS
SINGER
DESIZE SATURATOR
J BOX
DESIZE WASHER #1
CAUSTIC SATURATOR
J BOX
140°F
0.15mgd TO HEAT EXCHANGER & DRAIN
0.165mgd FEED (INCLUDES 0.034mgd FROM CAUSTIC RECOVERY UNIT)
0.012mgd LOSS
H_2O_2
WASHER #2
WASHER #3
PEROXIDE SATURATOR
J BOX
WASHER #4
FABRIC TO MERCERIZING OR PRINTING
140°F
0.12 mgd TO HEAT EXCHANGER AND DRAIN
FILTER
PUMP
0.132 mgd FEED

FIGURE II -1
SCHEMATIC DIAGRAM
BLEACHHOUSE ROPE RANGE

The synthetic and starch sizes are removed in the desize washer.

Rope Range Scouring/Bleaching. About 132,000 gpd are used for scouring and bleaching, which results in average water use of 2.2 gallons per lb of fabric. The wastewater flow of 120,000 gpd is discharged at about 140°F with other bleachhouse wastewater to a heat exchanger before flowing to the neutralization basin and final discharge.

Caustic and hydrogen peroxide are added for scouring and bleaching, and remaining size, oils, waxes, and other fiber impurities are removed in the washers.

Open Width Preparation Range Desizing/Scouring. The schematic diagram in Figure II-2 shows that about 143,000 gpd are used at this range, with 108,000 gpd used in the rinse portion and 35,000 gpd used in the desize/scour portion. The range processes about 25,000 pounds of fabric per day, resulting in an average water use of 5.7 gallons per pound of fabric. The wastewater flow of 130,000 gpd is discharged at about 175°F with other bleachhouse wastewater to a heat exchanger before flowing to the neutralization basin and final discharge to the sewer.

Generally, no chemicals are added except for detergents occasionally to remove synthetic sizes, oils, and other fiber impurities. The polyester/rayon fabrics are more easily cleaned than the cotton fabrics, thus precluding the need for chemicals such as caustic.

Mercerizing. The schematic diagram in Figure II-3 shows that about 100,000 gpd are used at the two ranges (50,000 gpd at each range). The mercerizing ranges process about 51,000 lb of fabric per day, resulting in an average water use of nearly 2 gallons per lb of fabric. About half of the water is used at the chain and spray washers and about 40,000 gpd flow to the caustic recovery system.

The details of the caustic recovery system are covered later in this section. About 50,000 gpd of mercerizing wastewater are discharged at about 175°F and, together with other bleachhouse wastewater, flow to a heat exchanger before flowing to the neutralization basin and final discharge to the sewer.

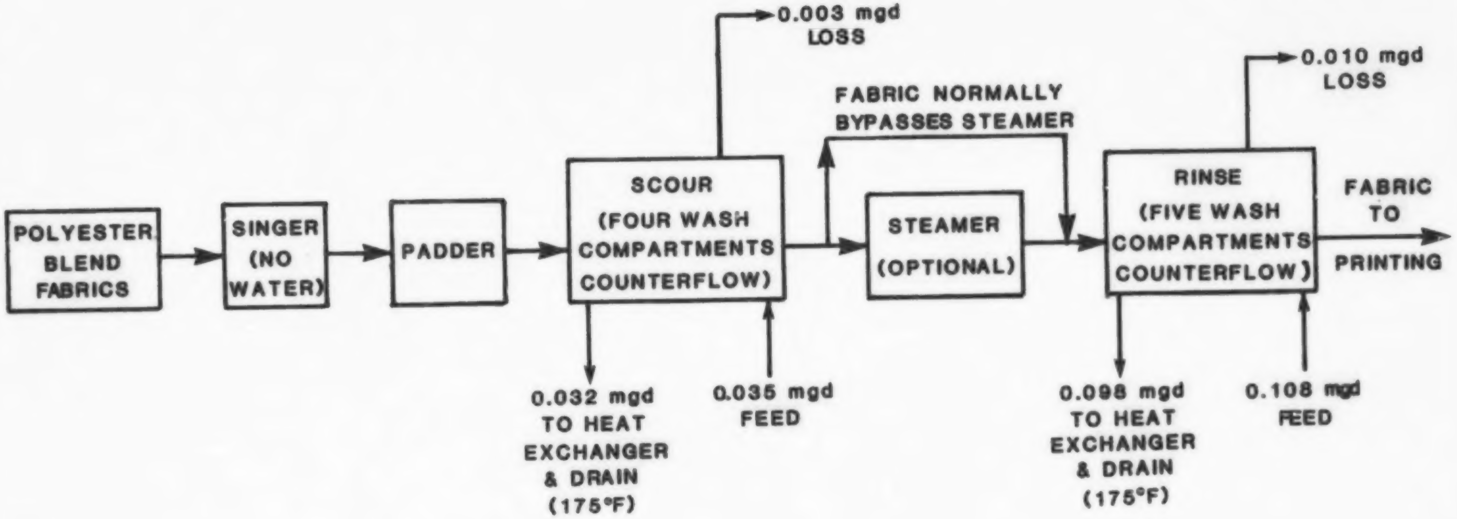

POLYESTER BLEND FABRICS
SINGER (NO WATER)
PADDER
SCOUR (FOUR WASH COMPARTMENTS COUNTERFLOW)
0.003 mgd LOSS
0.032 mgd TO HEAT EXCHANGER & DRAIN (175°F)
0.035 mgd FEED
FABRIC NORMALLY BYPASSES STEAMER
STEAMER (OPTIONAL)
RINSE (FIVE WASH COMPARTMENTS COUNTERFLOW)
0.010 mgd LOSS
0.098 mgd TO HEAT EXCHANGER & DRAIN (175°F)
0.108 mgd FEED
FABRIC TO PRINTING

FIGURE II-2
SCHEMATIC DIAGRAM
OPEN WIDTH PREPARATION RANGE

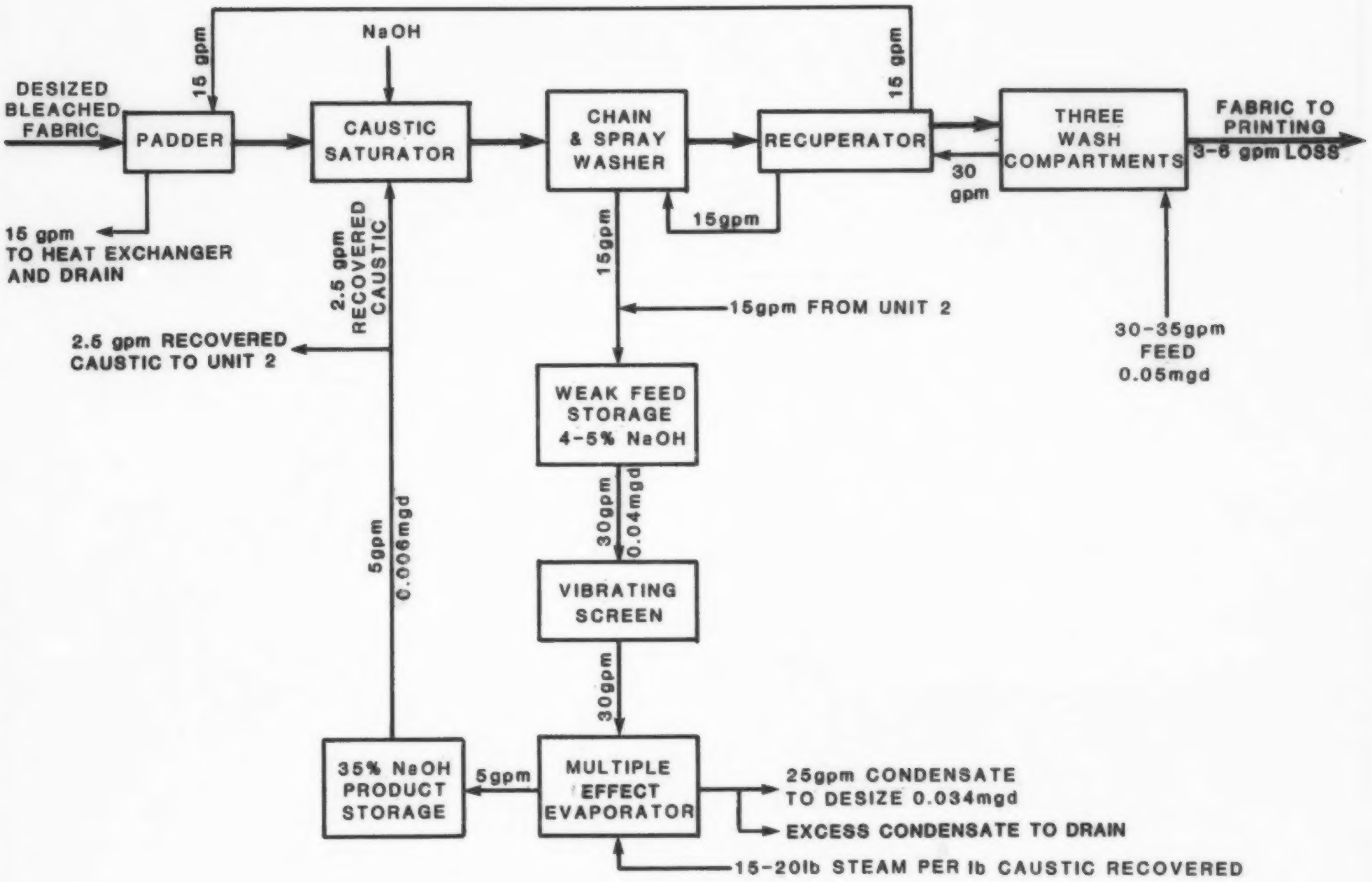

DESIZED
BLEACHED
FABRIC
PADDER
15 gpm
15 gpm
TO HEAT EXCHANGER
AND DRAIN
NaOH
CAUSTIC
SATURATOR
2.5 gpm
RECOVERED
CAUSTIC
2.5 gpm RECOVERED
CAUSTIC TO UNIT 2
CHAIN
& SPRAY
WASHER
15gpm
15gpm
15gpm FROM UNIT 2
RECUPERATOR
15 gpm
30
gpm
THREE
WASH
COMPARTMENTS
FABRIC TO
PRINTING
3-6 gpm LOSS
30-35gpm
FEED
0.05mgd
WEAK FEED
STORAGE
4-5% NaOH
30gpm
0.04mgd
VIBRATING
SCREEN
30gpm
MULTIPLE
EFFECT
EVAPORATOR
5gpm
35% NaOH
PRODUCT
STORAGE
5gpm
0.006mgd
25gpm CONDENSATE
TO DESIZE 0.034mgd
EXCESS CONDENSATE TO DRAIN
15-20lb STEAM PER lb CAUSTIC RECOVERED

FIGURE II -3
SCHEMATIC DIAGRAM
MERCERIZING AND CAUSTIC RECOVERY

Concentrated caustic (35-50% solution) is added at the caustic saturator to immerse the fabric in a 20-25% caustic solution to effect the mercerization process. The major portion of the caustic is subsequently washed off at the chain and spray washers.

Wastewater Characterization

Rope Range - Desizing and Scouring/Bleaching.

Wastewater samples from rope range desizing and scouring/ bleaching were collected and analyzed, and the results are shown in Table II-1. As indicated in this table and Table I-3, these processes contribute a large part of the organic and solids load (68 percent of total BOD, 59 percent of total COD, 25 percent of TSS) to the mill's discharge, as a result of removal of starches, synthetic sizes, waxes, oils, and other fiber impurities.

It is interesting to note that both the desize and scour/ bleach portions of the range contribute similar loads of BOD, COD, and TSS, which leads to a question on the actual efficiency of the desize operation, i.e., how much size is actually removed in the desize portion of the range, and how much is removed in the scour/bleach portion. This question significantly affects the potential for application of reuse/ recycle technologies and is discussed further in the section on recycle/ reuse methods.

Open Width Preparation Range.

Wastewater samples from the open width preparation range were collected and analyzed, and the results are shown in Table II-2. This table and Table I-3 show that the desize/scour portion of the open width preparation range contributes a significant organics and solids load to the mill effluent (13 percent of the BOD, 14 percent of the COD, and 12 percent of the TSS). A wide range in daily values for BOD and TSS is noted, perhaps due to the variety of fabrics processed at the range. It is evident, however, that the rinse portion is relatively clean in comparison with the desize/scour portion, and this indicates a potential for water reuse at the range itself. This is discussed further in the section on recycle/reuse methods.

TABLE II-1
ROPE RANGE WASTEWATER

	Concentration, mg/l					
	Desize Wash			Scour/Bleach Wash		
Alkalinity (as $CaCO_3$)	0	0	0	4,170	4,060	3,080
Total Carbon (% by weight)	0.2	0.22	0.12	-	-	-
BOD	2,850	3,500	1,520	2,450	2,750	2,120
COD	5,040	5,600	3,450	5,600	6,630	5,400
TDS	2,200	3,450	2,550	7,400	10,550	9,670
TSS	830	790	490	340	630	270
Oil & Grease	73	53	88	480	53	90
Phenolics	0.14	0.06	< 0.01	0.032	0.049	0.13
Turbidity (NTU)	230	85	120	280	550	310
Hardness (as $CaCO_3$)	150	57	100	110	120	91
Sodium	140	160	61	4,150	3,180	3,280
Chromium	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Copper	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Iron	1.1	0.41	0.46	0.74	0.95	0.75
Manganese	< 0.1	< 0.1	< 0.1	0.12	0.13	0.12
Zinc	0.21	0.19	0.12	0.17	0.15	0.14
pH (SU)	-	6.2	6.8	-	11.5	11.7
Temperature (°F)	135	147	136	135	136	135

Source: Wastewater samples taken May 17 to 21, 1982.

TABLE II-2

OPEN WIDTH PREPARATION RANGE WASTEWATER

	Concentration, mg/l					
	Desize/Scour Wash			Rinse Wash		
Alkalinity (as $CaCO_3$)	35	32	21	6.3	7.4	8.4
MBAS (as LAS)	0.22	0.2	0.44	0.058	0.034	0.04
BOD	6,000	2,400	3,000	180	72	120
COD	12,200	8,900	9,520	300	32	160
TDS	2,300	3,120	3,340	110	970	< 1
TSS	5,200	1,110	250	66	20	10
Oil & Grease	130	140	360	44	100	180
Phenolics	< 0.01	0.032	0.021	< 0.01	< 0.01	< 0.01
Turbidity (NTU)	1,200	450	250	24	23	14
Hardness (as $CaCO_3$)	< 1	< 1	< 1	8.1	< 1	< 1
Sodium	-	-	-	23	-	-
Chromium	-	-	-	< 0.1	-	-
Copper	-	-	-	< 0.1	-	-
Iron	-	-	-	0.26	-	-
Manganese	-	-	-	< 0.1	-	-
Zinc	-	-	-	< 0.1	-	-
pH (SU)	-	6.2	7.2	-	6.4	6.5
Temperature (°F)	180	175	169	180	167	169

Source: Wastewater samples taken May 17 to 21, 1982.

Mercerizing. Wastewater samples from the excess mercerizing wastewater (the portion that discharges to drain, as opposed to caustic recovery) were collected and analyzed, and the results are shown in Table II-3. This table and Table I-3 indicate that the wastewater is dilute, clear, and relatively pure; therefore, it has good potential for reuse in an area that may be enhanced or unaffected by the alkalinity and pH, which range around 900 mg/l as $CaCO_3$ and 11.0, respectively. Reuse of this wastewater at the desize washer is discussed later in this section.

DESCRIPTION OF APPLICABLE RECYCLE/REUSE METHODS

The methods for wastewater recycle/reuse in the bleachhouse are discussed under the following categories:

- Flow reduction and direct reuse measures.
- Ultrafiltration of desizing/scouring wastewater for size separation and water recycle.
- Evaporation of mercerizing wastewater for caustic recovery and water recycle.

Flow Reduction and Direct Reuse Measures

It is useful to first consider means to reduce flow at the various processes in order to minimize the costs involved in treating and recycling and to achieve savings in sewer use charges. The overall water use at the rope range averages nearly five gallons per pound of fabric, with 2.75 gallons per pound from desizing and 2.2 gallons per pound from scouring/bleaching. The water use at the open width preparation range averages 5.7 gallons per pound of fabric. Since ultrafiltration (UF) is a potential technology for treating wastewater from the rope range desizing and the open width desizing/scouring, it should be noted that economical applications of UF for size removal have been achieved with water use rates of about one gallon per pound of fabric.

A revised flow diagram incorporating direct reuse, flow reduction, UF treatment, and recycle in the bleachhouse is illustrated in Figure II-4. The diagram shows that the input to the rope range desize washer is decreased from 165,000 gpd to 120,000 gpd, and it consists of

TABLE II-3
MERCERIZER WASTEWATER

	Concentration, mg/l		
Alkalinity (as $CaCO_3$)	270	1,050	1,400
BOD	63	22	44
COD	42	54	62
TDS	360	1,200	2,160
TSS	23	10	30
Chloride	15	-	-
Phenolics	0.009	< 0.01	0.0015
Turbidity (NTU)	5.6	7.5	10
Hardness (as $CaCO_3$)	28	20	< 1
Sodium	260	-	190
Chromium	< 0.1	-	-
Copper	< 0.1	-	-
Iron	0.35	-	-
Manganese	< 0.1	-	-
Zinc	< 0.1	-	-
pH (SU)	10.4	11.0	11.4
Temperature (°F)	172	169	167

Source: Wastewater samples taken May 17 to 21, 1982.

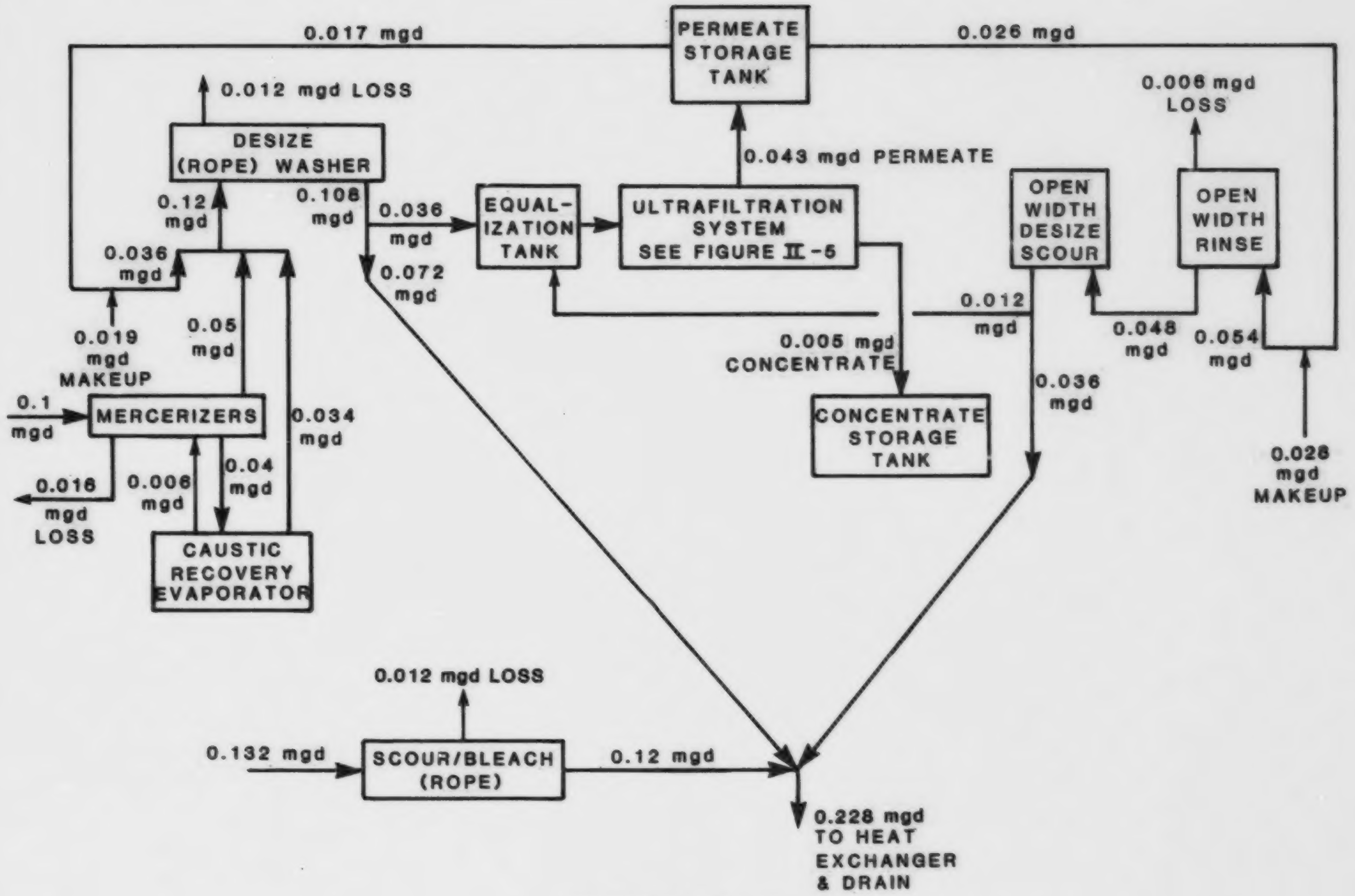

0.017 mgd
PERMEATE STORAGE TANK
0.026 mgd
0.012 mgd LOSS
DESIZE (ROPE) WASHER
0.006 mgd LOSS
0.043 mgd PERMEATE
0.12 mgd
0.108 mgd
0.036 mgd
EQUAL-IZATION TANK
ULTRAFILTRATION SYSTEM SEE FIGURE II -5
OPEN WIDTH DESIZE SCOUR
OPEN WIDTH RINSE
0.036 mgd
0.072 mgd
0.012 mgd
0.019 mgd MAKEUP
0.05 mgd
0.005 mgd CONCENTRATE
0.048 mgd
0.054 mgd
0.1 mgd
MERCERIZERS
0.034 mgd
CONCENTRATE STORAGE TANK
0.036 mgd
0.016 mgd LOSS
0.006 mgd
0.04 mgd
0.028 mgd MAKEUP
CAUSTIC RECOVERY EVAPORATOR
0.012 mgd LOSS
0.132 mgd
SCOUR/BLEACH (ROPE)
0.12 mgd
0.228 mgd TO HEAT EXCHANGER & DRAIN

FIGURE II -4
SCHEMATIC DIAGRAM
BLEACH HOUSE REUSE/RECYCLE

34,000 gpd of evaporation condensate from the caustic recovery unit (already in place), 50,000 gpd of water reuse from the mercerizers, 17,000 gpd from ultrafiltration permeate, and 19,000 gpd of fresh heated makeup water from the mill pond and bleachhouse heat exchanger. The wastewater discharge from the unit is 108,000 gpd, of which 36,000 gpd is fed to the ultrafiltration system, and 72,000 gpd is discharged to the heat exchanger and drain. The flow to the ultrafiltration system is planned such that wastewater from PVA desizing is segregated by pre-testing fabrics for their size type, and it is estimated that one-third of the desizing flow is associated strictly with PVA desizing. Currently no data are available to support the estimate other than observations by mill personnel, so this is in need of further investigation. The input to the open width preparation range is decreased from 143,000 gpd to 54,000 gpd by employing complete counterflow and balancing the needs of the rinse and scour/desize portions of the range. Of the 48,000 gpd discharged, about one fourth or 12,000 gpd is estimated to be related to PVA desizing and is fed to the ultrafiltration system. The remaining 36,000 gpd is discharged to the bleachhouse heat exchanger and to drain.

The total feed to the UF system is therefore estimated at 48,000 gpd, which results in about 43,000 gpd of permeate and 5,000 gpd of concentrate. The permeate can be recycled in various proportions to the rope and open width preparation ranges, and one scheme is shown that divides the recycle in proportion to the requirement at each range. Thus, 17,000 gpd are recycled to the rope range desize washer and 26,000 gpd to the open width preparation range.

Ultrafiltration of Desizing/Scouring Wastewater for Size Separation and Water Recycle

A description of ultrafiltration technology and its applicability in the textile industry is found in Volume 1.

The system planned for this application is illustrated in Figure II-5. The desize wastewater containing PVA is passed through a vibrating screen filter for solids removal before entering a continuous multi-stage feed and bleed ultrafiltration system. The hot permeate is recycled to the rope and/or open width preparation ranges, and the concentrate is stored until it is hauled for disposal or marketing.

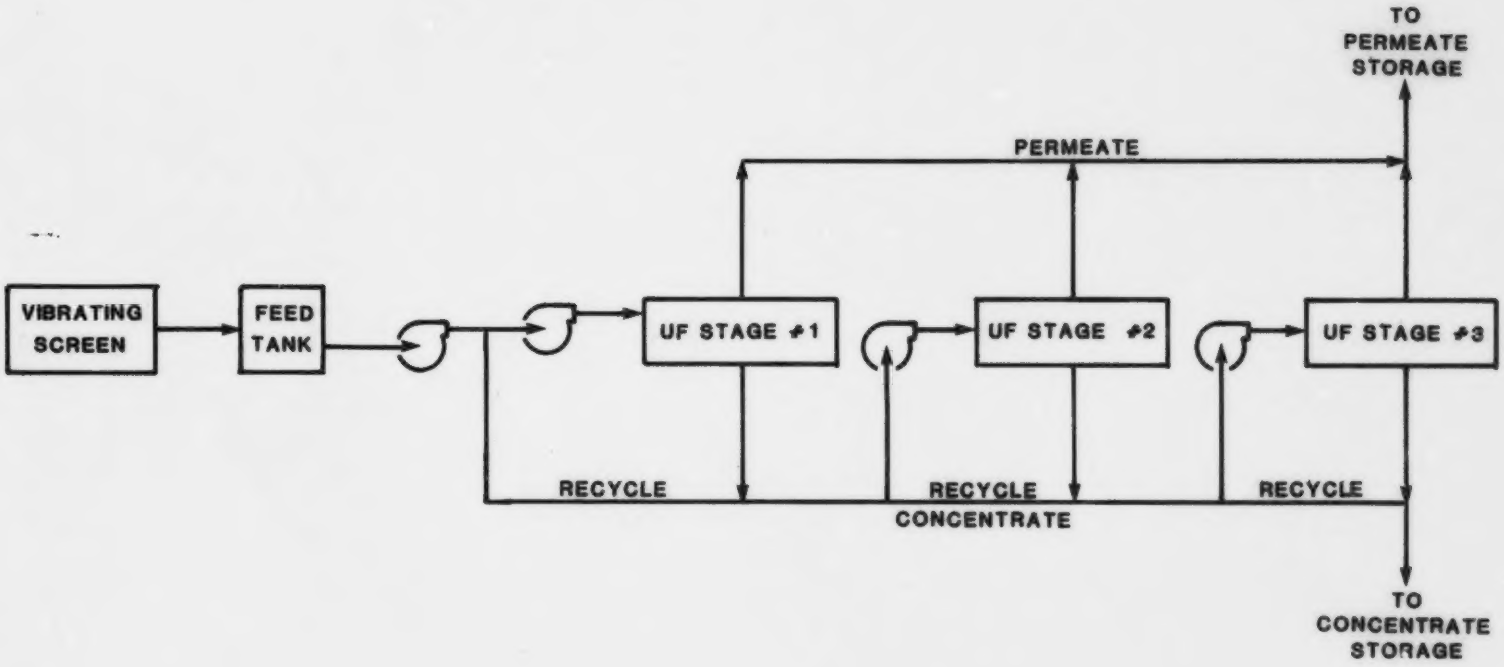

TO
PERMEATE
STORAGE
PERMEATE
VIBRATING SCREEN
FEED TANK
UF STAGE #1
UF STAGE #2
UF STAGE #3
RECYCLE
RECYCLE
RECYCLE
CONCENTRATE
TO
CONCENTRATE
STORAGE

FIGURE II -5
ULTRAFILTRATION SYSTEM SCHEMATIC
CONTINUOUS MULTI-STAGE FEED AND BLEED OPERATION

TECHNICAL FEASIBILITY

Flow Reduction and Direct Reuse Measures

Rope Range. An essential question affecting the ability to reduce flows at the ranges is the efficiency of the desizing operations. Wastewater data indicate, as stated earlier, that size may not be adequately removed in the rope range desizing operation and that substantial amounts may be present in the scour/bleach wastewater. One factor that may affect the desizing efficiency is the temperature of 140°F, which is lower than other known desizing operations of a similar type (see Mill W-8 of this study and Volume 1) that operate closer to 175°F.

Another factor is the nature of the chemical reaction involving sodium bromite for starch and PVA removal. This reaction is typically recommended to occur at pH above 9 for starch removal (Trotman, p. 210)*, and wastewater data indicate that the desize washwater is discharged at a pH of 6 to 7. The extent to which starch and PVA sizes are broken down in this process is an important factor in the success of the UF treatment process, which is discussed in the subsection on UF feasibility.

The reuse of hot condensate from the Zaremba caustic recovery unit in the desize washers should not have an effect on desizing efficiency.

Desizing efficiency may be affected by direct reuse of the portion of the mercerizing wastewater that is currently discharged directly to drain. Since this wastewater is fairly clean relative to the rope range desize wastewater, as shown in Tables II-1 and II-3, it has the potential for direct reuse at the rope range desize washer. Water saving and energy benefits can be realized if the pond water input flow to the desize washer is subsequently lowered. The effects of the alkalinity and temperature of the mercerizer wastewater on desizing efficiency need to be investigated.

Counterflow rinse is already installed on the scour/bleach portion of the rope range, and it is not apparent that flows can be reduced without affecting the efficiency of the operation. Again, the temperature of 140°F is lower than expected (Trotman, p. 254), and conceivably water use could be reduced if the temperature were raised, but the energy costs would likely exceed the water use savings. It would become economical only if it could be shown to be essential for the economic success of a UF or other treatment system to be discussed in the section on UF treatment.

---

*Trotman, Dyeing and Chemical Technology of Textile Fibers, 5th Edition.

Open Width Preparation Range. The water use at this range averages about 5.7 gallons per pound of fabric, and the wastewater data in Table II-2 indicate that the rinse portion of the range generates a very dilute wastewater in terms of organics and solids. Thus, this portion of the range has good potential for reuse at the desize/ scour portion of the range, through a complete counterflow arrangement from the rinse to scour portion. It is likely also that direct water reduction can be achieved because the major portion of the impurities is removed in the scour portion of the range. This is consistent with the concept that polyester fabrics are more easily cleaned than cotton fabrics. It has been demonstrated at another mill (Mill W-4 of this study) that a water use of one gallon per pound of fabric is achievable for open width scouring/desizing of polyester fabrics. Therefore, the projected water use of two gallons per pound here appears reasonable, though testing is necessary to establish that the fabrics are sufficiently scoured and desized in preparation for printing and finishing. Careful monitoring of flows will be necessary to conduct tests to establish optimum flow rate. Such monitoring and testing have never been conducted at this mill.

Ultrafiltration (UF)

The general history and background of UF in the textile industry is found in Volume 1, so the discussion here will focus on its applicability for the rope and open width preparation ranges.

A bench scale test of UF was conducted by Abcor, Inc. on the rope range desizing wastewater and the open width desizing/scouring wastewater. Phase separation was demonstrated for both streams, but the following results indicate that starch is degraded extensively at the rope range and passes through the UF membrane:

Rope range desize COD = 5,250 mg/l.*

UF Permeate - rope range desize COD = 2,180 mg/l.*

Open width desize/scour COD = 12,455 mg/l.*

UF Permeate - open width desize/scour COD = 970 mg/l.*

* Bench scale test conducted May 21, 1982.
COD test performed by Mill W-3 on May 21 and 24, 1982.

The extent to which starch and PVA are removed and chemically altered in the different portions of the rope range is one major issue involved with the application of UF for the rope range. Indicator parameters such as BOD, COD, and TSS show that size may be removed partially at both the desize and scour/bleach portion of the range, and further technical investigations are needed to determine the efficiency of the desizing operation.

The state of degradation of the starch and PVA is in need of investigation to determine the potential for complete rejection in a UF membrane and to project the nature of the concentrate and permeate.

The results for the open width range are somewhat more promising and indicate that the synthetic sizes do not pass through the membrane as extensively as the starch sizes generally expected at the rope range.

Mill personnel are uncertain as to amounts and types of size on the fabrics that are processed on this range, so investigations similar to those needed for the rope range must be conducted on this range. Wastewater data show that the vast majority of the organic and solids load results in the scour/desize portion of the range and not in the rinse portion, which indicates that size removal occurs only on the scour/desize portion of the range. However, testing must establish the amount, type, and extent of degradation of the size material in the wastewater.

The results of such investigations on the two ranges significantly affect the planning of a UF system. It is necessary to make some assumptions to examine the economics of a UF system on a preliminary basis. Most research has shown that the best applications of UF have been for PVA recovery and that starch is generally degraded to the extent that it cannot be reused.

Therefore, the planned system depends on the ability to segregate the fabrics such that PVA is the major size constituent in the wastewater. Testing and statistical data are needed to establish the percentage of the fabrics that are sized with PVA and to project a flow rate for the UF system.

Further investigations are needed to establish the usefulness and value of the permeate and concentrate of a UF system at this mill. One UF manufacturer with experience in the region has stated that there may be a nearby market for the UF concentrate at paper mills, which sometimes use a starch/PVA mixture as a binder.

ECONOMIC FEASIBILITY

The discussion of Technical Feasibility offers many unanswered questions regarding water reduction and ultrafiltration in the bleachhouse. Therefore, the following range of possible conditions is explored in this discussion:

1. Direct reuse of mercerizer wastewater and open width rinse water only.
2. Direct reuse plus ultrafiltration of 20 gpm from the rope range and 6 gpm from the open width range.
3. Direct reuse plus ultrafiltration of 32 gpm from the rope range and 10 gpm from the open width range.
4. Direct reuse plus ultrafiltration of 44 gpm from the rope range and 15 gpm from the open width range.

The benefits of size recovery are evaluated over a range of recoverable chemical values from no value to $1 per pound.

The benefits, costs, and paybacks under the various conditions are summarized in Table II-4. The benefits are illustrated further in Table II-5, and the costs in Table II-6.

The benefits and costs are calculated on the basis of the following:

- Wastewater discharge at \$0.43/1000 gallons (estimated from mill records).
- BOD surcharge of \$0.13 per lb of BOD in concentrations exceeding 100 mg/l.
- Energy cost of \$5.14/10^6 BTU.
- Electricity cost of \$0.0743 per Kwhr.
- Existing heat exchanger typically heats incoming pond water from 110 to 132°F with bleachhouse wastewater entering at 152°F and discharging at 132°F. Reused hot water is expected to average 150°F.
- Manufacturing processes operate 250 days/yr.
- UF system operates 7 days/wk (provided with adequate automation and storage) and recovers 80 percent of size; PVA is applied at 8 percent of weight of fabric.
- Capital costs are estimated in 1982 dollars on the basis of previous studies and equations in Volume 1.
- O&M costs for UF are based on equations developed in Volume 1.

Tables II-4 through II-6 illustrate that direct reuse is economically attractive because of the wastewater and energy savings and relatively small capital and annual costs.

Ultrafiltration is economically attractive only if substantial value (close to \$1 per pound) can be attributed to the recovered chemical (size). No payback is expected if a market for the recovered size is not available; i.e., the savings from wastewater and BOD discharge reductions and energy reductions are not adequate to offset the relatively high capital and annual costs for UF.

ENVIRONMENTAL EFFECTS

Direct reuse and water reduction are expected to have little or no effect on pollutant loads, because the streams involved are relatively clean and contribute relatively small amounts of pollutants. This is evident in Table I-3, which shows that the open width rinse and mercerizer rinse contribute less than 2 percent of the BOD, and less

TABLE II-4

SUMMARY OF BLEACHHOUSE ECONOMICS

(CAUSTIC RECOVERY covered separately)

Scheme:		1	2	3	4
Annual Savings		Reuse only	Reuse + UF (26 gpm)	Reuse + UF (42 gpm)	Reuse + UF (59 gpm)
Totals w/chemical recovered at:	$ 1/lb	$50,000	$407,000	$589,000	$774,000
	0.75/lb	50,000	327,000	469,000	614,000
	0.50/lb	50,000	247,000	349,000	454,000
	0.25/lb	50,000	167,000	229,000	294,000
	0.0/lb	50,000	87,000	109,000	139,000
Costs					
Capital		$24,000	$615,000	$899,000	$1,173,000
Annual Operating		$ 500	$ 81,000	$116,000	$144,000
Payback Period (years)					
Chemical value of:	$ 1/lb	0.48	1.9	1.9	1.9
	0.75/lb	0.48	2.5	2.5	2.5
	0.50/lb	0.48	3.7	3.9	3.8
	0.25/lb	0.48	7.2	8.0	7.8
	0.0/lb	0.48	no payback	no payback	no payback

TABLE II-5

BLEACHHOUSE SUMMARY - SAVINGS ($/yr.)

	Scheme:	1 Reuse only	2 Reuse + UF (26 gpm)	3 Reuse + UF (42 gpm)	4 Reuse + UF (59 gpm)
Wastewater		$18,700	$ 23,900	$ 27,000	$ 30,300
BOD		(2,500)	20,000	34,000	49,000
Energy		34,000	43,000	48,000	55,000
		$50,000	$ 87,000	$109,000	$134,000
Chemical at	$ 1/lb	-0-	$320,000	$480,000	$640,000
	0.75/lb	-0-	240,000	360,000	480,000
	0.50/lb	-0-	160,000	240,000	320,000
	0.25/lb	-0-	80,000	120,000	160,000
	0.0/lb	-0-	-0-	-0-	-0-
Totals w/chemical at	$ 1/lb	$50,000	$407,000	$589,000	$774,000
	0.75/lb	50,000	327,000	469,000	614,000
	0.50/lb	50,000	247,000	349,000	454,000
	0.25/lb	50,000	167,000	229,000	294,000
	0.0/lb	50,000	87,000	109,000	134,000

TABLE II-6

BLEACHHOUSE COST SUMMARY

Scheme:	1 Reuse only	2 Reuse + UF (26 gpm)		3 Reuse + UF (42 gpm)	4 Reuse + UF (59 gpm)
Capital Cost UF System	-0-	$406,000		$591,000	$770,000
Piping	9,000	3,000 +9,000 12,000	add from Scheme 1	3,600 +9,000 12,600	4,000 +9,000 13,000
Pumps	8,000	8,000 +8,000 16,000	add from Scheme 1	10,000 +8,000 18,000	12,000 +8,000 20,000
Storage	3,000	100,000 Scheme 1 not added (insignificant)		158,000	215,000
Electrical	3,000	61,000		89,000	116,000
Engineering	1,000	20,000		30,000	39,000
Total Capital	$24,000	$615,000		$898,600	$1,173,000
Annual Costs UF Operating & Maintaining		$ 80,000		$115,000	$143,000
Pumping	Insignificant, based on caustic recovery calculations				
Misc. O&M	$ 500	$ 1,000		$ 1,000	$ 1,000
Total Annual	$ 500	$ 81,000		$116,000	$144,000

than 1 percent of the COD and TSS loads. Tables II-2 and II-3 indicate that no other pollutants are expected to be affected significantly by direct water reuse.

The effects of an ultrafiltration system depend on the flow that is treated. As shown in Table I-3, the desize washer of the rope range contributes significant loads of BOD, COD and TSS, and these loads could be drastically reduced by ultrafiltration and reuse of the UF permeate. Reuse of wastewater from the open width scour range would effect further reduction in these parameters in the final effluent. Calculations for BOD surcharges show that up to a 40 percent decrease in final effluent BOD load is achievable, depending on the flow through UF treatment. This flow is determined by the quantity of PVA-sized fabric, for which data need to be collected. Similar reductions in COD and TSS are expected.

Tables II-1 and II-2 indicate that other pollutant parameters, such as metals and phenolics, are not affected by recycle/reuse measures in the bleachhouse.

CONCLUSIONS

1. Direct reuse of mercerizer wastewater and open width preparation rinse water is economically attractive and should be pursued by the mill.

2. Substantial additional research is needed to evaluate the desizing process and the potential for size recovery at this mill. Research needs are discussed under Technical Feasibility and include studies in the following areas:

   - Segregation of PVA-sized fabrics.
   - Desizing efficiency and effects of water reduction/reuse.
   - Size degradation.
   - Marketability of recovered size.
   - Effects of UF permeate on fabric quality, manufacturing processes, and pollutant discharge.

3. Ultrafiltration is costly and can be justified economically only if substantial chemical (size) value is recovered. This technology

should not be pursued until further research is conducted as indicated above.

EVAPORATION OF MERCERIZING WASTEWATER

A description of evaporation technology and its applicability in the textile industry is found in Volume 1.

The system already in place at this mill is illustrated in Figure II-3. A solution of 4 to 5% caustic is pumped from the chain and spray washers at the mercerizers to a weak feed storage tank. Lint and gross solids are removed at a vibrating screen before the wastewater enters the multiple effect evaporator, where it is concentrated to a 35% caustic solution. The caustic is returned to the caustic saturators at the mercerizers, and the hot condensate generally is pumped for reuse at the desize washer.

Technical Design Criteria

The evaporator system used at this mill for caustic recovery consists of a double effect evaporator with vertical steam chests. The second effect is operated under a vacuum. A Sweco vibrating screen filter removes particulate matter from the feed to the evaporator. Other technical data on the system are listed below:

Type of Evaporator and Manufacturer:	Double effect evaporator Zaremba (no longer in business)
Date of Installation:	Around 1970.
Average Caustic Recovery:	304,000 lb/mo (80% of amount used)
Average Concentration Achieved:	4% to 35-40%
Feedrate:	40,000 gpd
Steam Requirement:	20 lb steam/lb caustic recovered

Economic Feasibility

The benefits, costs and payback of caustic recovery are summarized in Table II-7. The benefits and costs are calculated on the following basis:

1. Wastewater discharge at $0.43/1000 gallons.
2. Energy cost of $5.14/10^6 BTU.
3. Electricity cost of $0.0743/Kwhr.
4. Caustic valued at $0.18/lb.
5. Existing heat exchanger heats incoming pond water to 132°F. Reused hot water averages 158°F with caustic recovery in place.
6. Current neutralization costs average $2,640 per month with caustic recovery in place.
7. Manufacturing process operates 250 days/year.
8. Capital and other O&M costs are estimated in 1982 dollars on the basis of previous studies and costs developed in Volume 1.

It is evident that the benefits of caustic recovery outweigh the costs sufficiently to make the technology economically attractive, as indicated by the 1 to 2 year payback period. The benefits are due to the value of the recovered chemical and the savings in neutralization costs.

It is conceivable that steam economy is actually somewhat better than the conservative value used in the estimate (20 lb steam/lb caustic recovered). Calculations indicate that values of 15 lb steam per lb caustic may be achievable, which would lower the payback period proportionately.

Environmental Effects

Tables I-3 and II-3 indicate that mercerizer wastewater is relatively clean with respect to pollutant parameters such as BOD, COD, TSS, phenolics, and metals. The primary effect of recycle/reuse of the wastewater is to decrease the alkalinity and pH of the effluent. The total alkalinity from the bleachhouse is decreased by about 80 percent by the caustic recovery system.

TABLE II-7

ECONOMICS OF EVAPORATION FOR CAUSTIC RECOVERY

Annual Savings	
Caustic recovery	$650,000
Neutralization savings	127,000
	$777,000
Capital Cost	
Evaporation Equipment	$480,000
Piping	3,000
Pumping	4,000
Storage	20,000
Electrical	72,000
Engineering	24,000
	$603,000
Annual Operating Costs	
Steam	$427,000
O&M Labor	20,000
O&M Materials	4,800
Pumping	50
	$452,000
Payback Period	$\frac{\$603,000}{\$325,000}$ = 1.9 yrs.

Conclusions

1. Caustic recovery by evaporation has been highly successful at the mill. Substantial savings have been realized due to chemical recovery and reduced neutralization costs.

2. Improvements in steam economy would reduce the payback period proportionately. Thus, higher caustic concentrations in the original feed would improve the economics, which are already attractive.

SECTION III

PRINT & COLOR SHOP WASTEWATER

DESCRIPTION OF MANUFACTURING PROCESSES AND WASTEWATER PRETREATMENT

Practically all of the fabrics to be finished at this mill are printed by the roller printing process described in the introduction. Although no water contacts the fabric other than the amount contained in proprietary color formulations, about 200,000 gallons per day are used in the print and color shop for cleaning floors and equipment and for other noncontact purposes described below.

Water Use

Table III-1 presents a summary of water use in the print and color shop in order of estimated flow rates. Conclusive evidence of the water needed and used in each area is not available. Therefore, the estimates are based primarily on mill personnel observations, with adjustments made to balance the flows with the total flow observed at the DAF treatment system.

Print Room

- Box and Brush Wash - Most of the water in the print room is used for the box and brush wash, in which flow from a hose is manually sprayed on boxes and brushes from print machines that are carried on carts into an enclosed 20' by 20' hose spraying area or booth. The hoses are sprayed until the operator is satisfied that color has been adequately removed from the boxes and brushes. The water is unheated pond water; as such, operators feel that the water is essentially "free" and use it liberally. The mill management has been trying to educate operators to be more cautious in their use of water because of escalating sewer use and pretreatment charges, but the education process is slow. Several hour-long observations conducted in this area showed that operators do not appear concerned with water use. Spraying times and frequencies varied widely. Currently there are two hoses, one a high-volume hose with average flow rate of 25-30 gpm, and the other an air-assisted low-volume hose, with an average flow rate of 15-20 gpm.

TABLE III-1

SUMMARY OF PRINT AND COLOR SHOP WATER USE

PRINT ROOM

Box and Brush Wash	41,000 gpd	
Machine Hoses	22,000 gpd	
Patching	9,000 gpd	
Wash Troughs	4,000 gpd	
Backgrey Washers	1,400 gpd	
Vacuum Pumps	500 gpd	
Total from Print Room	77,900 gpd	≃ 80,000 gpd

COLOR SHOP

Drum Washer	30,000 gpd	
Floor Washing	21,000 gpd	
Mixer Cleanup	21,000 gpd	
Dipper Tubs	7,000 gpd	
Total from Color Shop	79,000 gpd	≃ 80,000 gpd
Unaccounted for Balance		30,000 gpd
TOTAL TO DAF		190,000 gpd

Operators show a distinct preference for the high-volume hose and state that the air-assisted hose does not allow the water to strike the equipment strongly enough to dislodge the color. This is discussed further under water reduction measures.

- Machine Hoses - At each printing machine there is a hose to wash down the floor periodically. Flowrates of the individual hoses are shown in Table III-2, with estimates of the time per day that the hoses run. Observations in this area were inconclusive, and hoses are occasionally left to run indiscriminately.
- Patching - A series of sinks is filled and continuously flushed in order to test patches of printed fabric for color matching. Four faucets are left to run, resulting in 6 gpm around the clock.
- Wash Troughs - A series of troughs is located along the periphery of the printing room, in which miscellaneous equipment can be dipped for a quick rinse. The troughs are dumped and refilled two or three times per shift, according to mill personnel. Data on the troughs are summarized in Table III-2.
- Backgrey Washers - Five backgrey washers are incorporated with printing machines to wash lightweight nylon backgrey fabrics, as opposed to heavier cotton fabrics that are washed at the main backgrey washer in the soaphouse. Data on these backgrey washers are summarized in Table III-2.
- Vacuum Pumps - Pumps incorporated on the print machines for backgrey washer operation have a steady trickle discharge of water estimated as 100 gpd for each of the five pumps.

Color Shop

- Drumwasher - The most noticeable water use in the color shop is the automated drumwasher that scrubs used color drums so they may be reused for transporting other color

TABLE III-2

PRINT ROOM FLOW DATA

BOX AND BRUSH WASH

High Volume Hose - 30 gpm* for a maximum of 15 hours**/day = 27,000 gpd
Low Volume Hose - 20 gpm* for a maximum of 12 hours**/day = 14,400 gpd
Projected Water Use = 41,400 gpd

MACHINE HOSES

(Projected Running Time = 120 minutes/day**)

Machine No.	Flow Rate,* gpm	Flow, gpd
9	25	3,000
10	20	2,400
11	10	1,200
12	10	1,200
13	10	1,200
8	25	3,000
4	25	3,000
1	15	1,800
X	20	2,400
X	20	2,400
		21,600

PATCHING

6 gpm measured,* 24 hours/day**
8,640 gpd ≈ 9,000 gpd

WASH TROUGHS

3 Large Troughs, 8 cu. ft./trough (60 gal)
6 Small Troughs, 5-1/2 cu.ft./trough (40 gal)

3 x 3 Trough Dumps per shift** x 3 shifts/day x 60 gal/dump* = 1,620 gpd
6 x 3 Trough Dumps per shift** x 3 shifts/day x 40 gal/dump* = 2,160 gpd

TOTAL = 3,780 gpd ≈ 4,000 gpd

BACKGREY WASHERS

(at print machines)

5 machines x 45 gal/dump* x 3 dumps/day** = 675 gpd

+ 5 machines x 720 gal/dump* x 1 dump/wk** x $\frac{\text{wk}}{5 \text{ days}}$ = 720 gpd

Total Estimate = 1,400 gpd

---

* Measured during April & May, 1982.
** Estimate from observations and discussions in May, 1982.

formulations to the print machines. Cycle times and flowrates vary widely; data are presented in Table III-3.

- Floor Washing - Periodically the floor in the color shop is hosed down at varying flowrates and for varying times, depending on operator preference, and data are summarized in Table III-3.
- Mixer Cleanup - Color mixers are typically washed initially in tubs of dirty water, followed by a wash with clean water from a hose. The data on the clean water wash are summarized in Table III-3.
- Dipper Tubs - A series of tubs is available in several locations around the color shop for miscellaneous cleaning, usually for color dippers. Often the faucets are left to flush continuously except where operators are careful to close the valves. The data from the observations of these tubs are summarized in Table III-3.

Chemical Use and Wastewater Characteristics

The chemicals used in the various color formulations are proprietary, but generally they consist of dyestuffs, thickeners, pigments, and mineral spirits. The formulations vary with the type of fabric and the color pattern desired.

The washing of the equipment and floors results in a wastewater containing a highly colored colloidal suspension of many of the materials mentioned above. Composite samples of the wastewater, known heretofore as raw print wastewater, were collected just after a bar screen that precedes pumping to the raw print wastewater equalization basin. The results of the analyses of these samples are presented in Table III-4, along with the results from the DAF pretreatment process for comparison. Table III-4, in conjunction with Tables I-2 and I-3, indicates the highly colored and organic nature of the raw print wastewater.

Of course, it should be noted that the DAF treatment system removes contaminants to some extent before they are discharged to the city sewer with the other mill wastewater. This is discussed further in the subsection on Technical Feasibility.

TABLE III-3

COLOR SHOP FLOW DATA

DRUM WASHER	20 gpm measured as maximum per tub* 500 tubs/day estimated** 3 minutes/tub measured as maximum* 20 gpm/tub x 500 tubs/day x 3 minutes/tub = 30,000 gpd
FLOOR WASHING	30 gpm estimated as average hose discharge rate** 700 minutes/day in use estimated** 30 gpm x 700 min/day = 21,000 gpd
MIXER CLEANUP	30 gpm estimated as typical discharge rate** 700 minutes/day in use** 30 gpm x 700 min/day = 21,000 gpd
DIPPER TUBS	10 gpm estimated** 700 minutes/day in use estimated** 10 gpm x 700 min/day = 7,000 gpd

* Measured during May, 1982.
** Estimate from observations and discussions in May, 1982.

TABLE III-4
PRINT WASTEWATER

	Concentration, mg/l					
	Raw			Coag/DAF Treated		
Alkalinity (as $CaCO_3$)	410	340	310	63	26	40
MBAS (as LAS)	---	---	---	---	---	---
Total Carbon (% by weight)	---	---	---	---	---	---
BOD	2,700	3,400	1,050	550	680	1,000
COD	6,590	10,300	3,200	1,080	2,300	2,200
TDS	2,770	2,840	2,020	620	750	772
TSS	620	540	310	220	350	992
Chloride	140	80	80	830	760	760
Oil & Grease	51	360	780	28	97	34
Phenolics	3.83	9.33	3.15	1.54	1.38	1.87
Turbidity (NTU)	2,300	3,700	-	10	2.6	2.4
Color (ADMI)	17,600	19,200	12,400	300	870	929
Hardness (as $CaCO_3$)	< 1	50	40	89	50	< 1
Sodium	460	450	350	200	240	200
Chromium	18	29	5.5	1.3	11	7.3
Copper	20	9.5	4.0	0.86	4.3	3.5
Iron	11	3.0	3.4	50	64	230
Manganese	2.0	0.30	0.67	9.9	10	8.5
Zinc	4.0	1.6	0.42	0.72	1.1	0.80
pH (SU)	---	---	10.7	---	5.1	5.1
Temperature (°F)	88	82	84	81	82	88

Source: Wastewater samples taken May 17 to 21, 1982.

Existing Wastewater Pretreatment

The system in place at this mill for treatment of raw print wastewater is illustrated in Figure III-1. The entire discharge of raw print wastewater, 0.19 mgd, flows to an equalization basin, from which it is pumped at about 125 gpm to the DAF clarifier. Ferric chloride and polymer are fed in-line at an average 600 mg/l $FeCl_3$ and 20 mg/l polymer immediately before about 0.1 mgd of recycled pressurized clarifier effluent are fed near the entry to the DAF clarifier. Design and operating data on the DAF are summarized in Table III-5.

Float solids are dewatered on a belt press and hauled to a landfill. The belt press includes a reactor-thickener that discharges about 40,000 gpd along with the clarifier effluent, for a total discharge of 230,000 gpd. None of this discharge is currently reused.

The performance of the existing system is discussed under Technical Feasibility and Economic Feasibility.

DESCRIPTION OF APPLICABLE RECYCLE/REUSE METHODS

The methods for wastewater recycle/reuse in the print and color shop are discussed under the following categories:

- Flow reduction and direct reuse measures
- Coagulation/flotation for water recycle

The applicable methods for wastewater recycle/reuse are incorporated in the flow diagram of Figure III-2. It is projected that water use can be cut by about one-third by measures discussed under Technical Feasibility, so the input to the DAF treatment system is decreased from 190,000 gpd to 127,000 gpd.

Approximately 100,000 gpd of DAF effluent are pumped to a storage tank for reuse in equipment cleaning in the print and color shop. The remaining 27,000 gpd are discharged to the sewer to avoid a large buildup of impurities, and this is made up with pond water, generally to be used in the final stage of cleaning the various pieces of equipment.

An additional note is that it is projected that improvements in the existing DAF system can cut polymer dosage from 20 to 5 mg/l. This is discussed under Technical Feasibility.

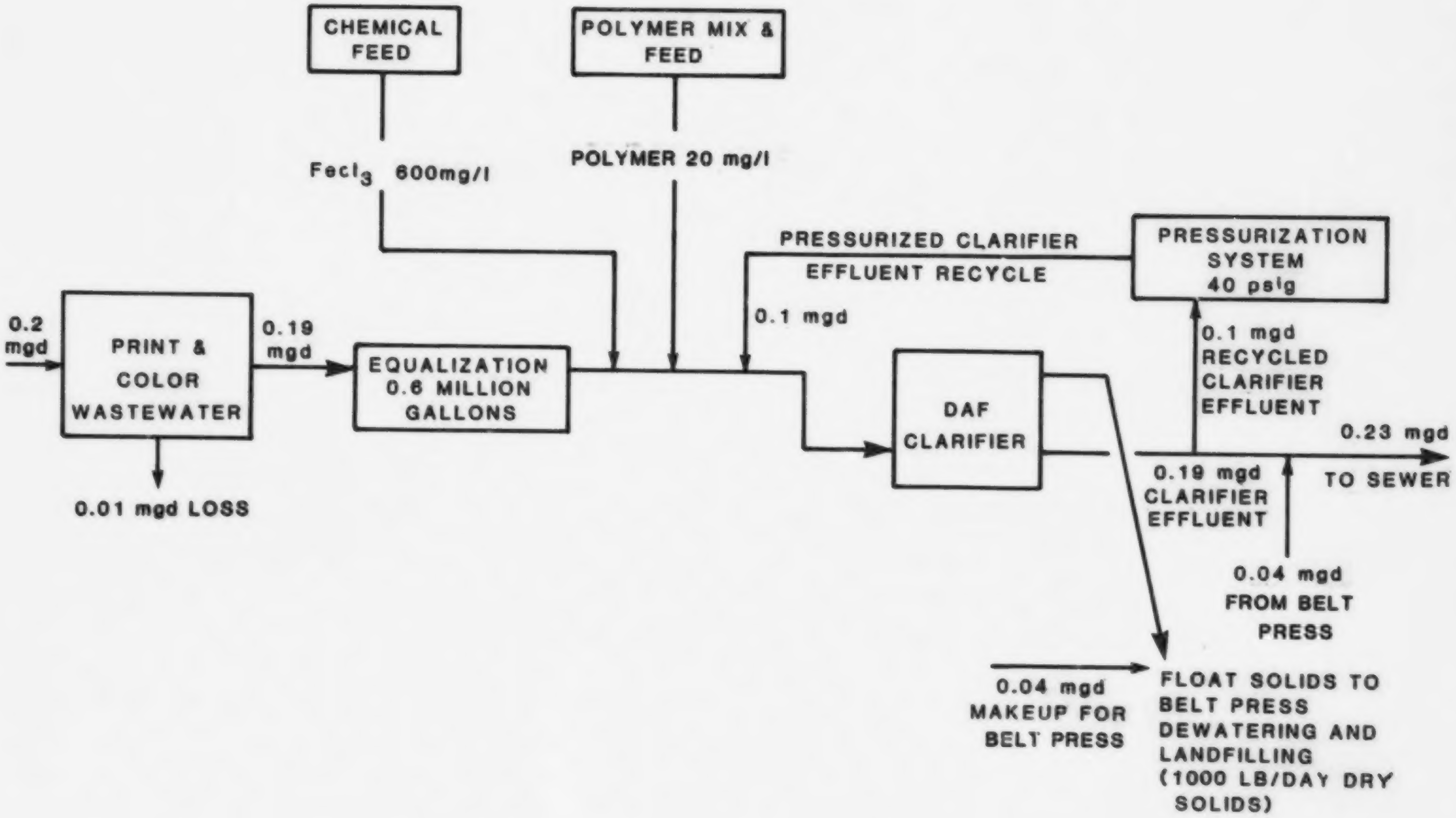

CHEMICAL FEED
POLYMER MIX & FEED
$FeCl_3$ 600mg/l
POLYMER 20 mg/l
PRESSURIZED CLARIFIER EFFLUENT RECYCLE
PRESSURIZATION SYSTEM 40 psig
0.2 mgd
PRINT & COLOR WASTEWATER
0.19 mgd
EQUALIZATION 0.6 MILLION GALLONS
0.1 mgd
0.1 mgd RECYCLED CLARIFIER EFFLUENT
DAF CLARIFIER
0.23 mgd
TO SEWER
0.19 mgd CLARIFIER EFFLUENT
0.01 mgd LOSS
0.04 mgd FROM BELT PRESS
0.04 mgd MAKEUP FOR BELT PRESS
FLOAT SOLIDS TO BELT PRESS DEWATERING AND LANDFILLING (1000 LB/DAY DRY SOLIDS)

FIGURE III-1
SCHEMATIC DIAGRAM
COAGULATION/DAF FOR PRINTING WASTEWATER

TABLE III-5
COAGULATION/DAF SUMMARY
DESIGN AND OPERATING DATA

Raw Print Wastewater Flow Rate:	200,000 gpd; 125 gpm feed to DAF
Equalization Volume:	0.6 million gallons
Type & Dosage of Coagulants:	600-700 mg/l $FeCl_3$ 10-20 mg/l polymer
Mixing & Flocculation Facilities:	In line and at DAF
pH Control:	Obtained with $FeCl_3$ dose to pH 5-5.5
Type & Size of DAF Unit:	20 foot diameter, Infilco Degremont, Inc.
Typical Solids Loading:	0.1 lb/sq ft/hr
Hydraulic Loading:	0.6 gpm/sq ft
Air to Solids Ratio:	0.02 - 0.04
Air Pressure:	40 psig
Recycle Ratio:	50%

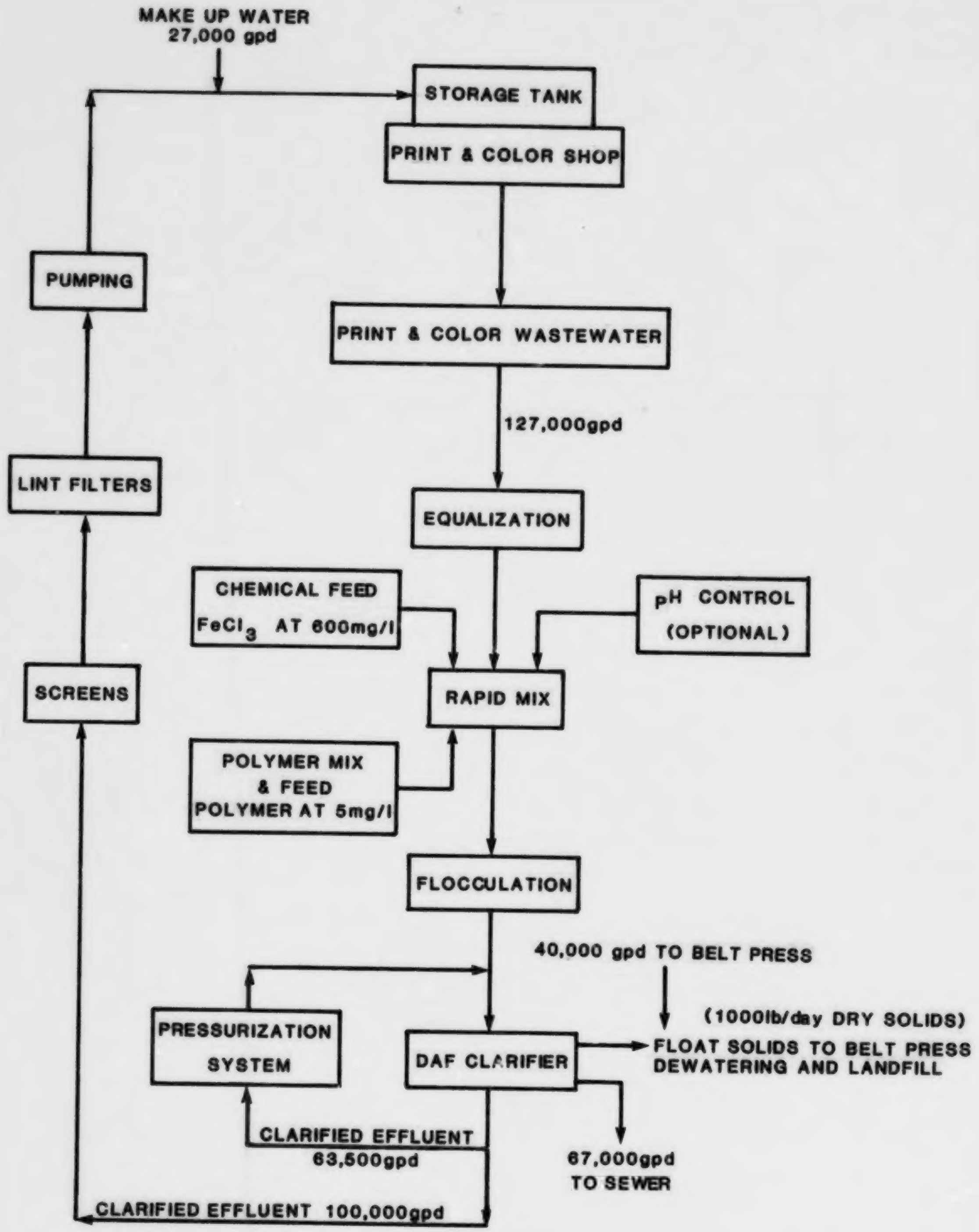

MAKE UP WATER
27,000 gpd
STORAGE TANK
PRINT & COLOR SHOP
PUMPING
PRINT & COLOR WASTEWATER
127,000gpd
LINT FILTERS
EQUALIZATION
CHEMICAL FEED
FeCl3 AT 600mg/l
pH CONTROL
(OPTIONAL)
SCREENS
RAPID MIX
POLYMER MIX
& FEED
POLYMER AT 5mg/l
FLOCCULATION
40,000 gpd TO BELT PRESS
(1000lb/day DRY SOLIDS)
PRESSURIZATION
SYSTEM
DAF CLARIFIER
FLOAT SOLIDS TO BELT PRESS
DEWATERING AND LANDFILL
CLARIFIED EFFLUENT
63,500gpd
67,000gpd
TO SEWER
CLARIFIED EFFLUENT 100,000gpd

FIGURE III -2
RECYCLE / REUSE FOR PRINT & COLOR SHOP
WASTEWATER FLOW DIAGRAM OF COAGULATION / DAF SYSTEM

TECHNICAL FEASIBILITY

Flow Reduction and Direct Reuse Measures

As described in the subsection on water use, the mill does not carefully control or monitor the use of water in the print and color shop. It is recommended that the areas of largest water use, such as the box and brush washing, floor washing, and drum washing, be metered and that observations be made to establish a means to control the indiscriminate use of water. In addition to a continuation of education programs, both formal and informal, a system of incentives could be devised to reward operators for improvements in controlling water use. Several specific suggestions for water reduction follow, but it should be noted that the list is far from exhaustive, and imaginative measures are constantly in need of development.

Box & Brush Wash. As mentioned earlier, the mill has an air-assisted hose and a traditional high volume hose, and thus far, operators have continued to use the high-volume hose. Observations showed that the air-assisted hose can do as good a job of cleaning as the high-volume hose, provided the operator stands fairly close to the equipment so that the water strikes with adequate force. The first step in water reduction is to educate and convince the operators that this is the case and that the high-volume hose is rarely needed.

A similar hosing operation is performed at a nearby mill of the same parent company, and the air-assisted hose flowrate is about 10 gpm, as opposed to about 20 gpm for the air-assisted hose at this mill and 30 gpm for the high-volume hose. Although the material may be somewhat more easily removed at the other mill since screens are used for printing instead of rollers, there is evidence that flows can be reduced in this area by one-third by using the air-assisted hose almost exclusively.

Floor Washing. This is an area in which indiscriminate water use is often observed, especially in the color shop. One specific suggestion, based on observations at the company's other mill nearby, is to wash all mixers and other equipment in a confined space against a wall, instead of spread around the room as is currently done.

It is projected that floor washing flows could be cut by at least one third by judicious planning of the space, similar to the measures at the other mill. A variation is to plan containment areas for spills immediately around the color mixing area, so that the color would have less floor space on which to spread. Nozzles on the hoses would be a simple measure for more efficient cleaning. A system of incentives for spill control could be devised to promote a sense of better housekeeping in general and to prevent serious loss of valuable color formulations.

Drum Washing. It is suspected that cycle times could be reduced for many of the drums, though admittedly some are difficult to clean adequately. At the company's other nearby mill, the drum washer's typical cycle is one minute, but the formulations are aqueous solutions that are easier to clean.

Sumps for Direct Reuse. Mill personnel often suggest that water from the drum washing, floor washing, and box and brush washing could drain to a central nearby sump and be pumped back for direct reuse. A screen and lint filter are necessary to avoid clogging hose and machinery nozzles, and it is known that this idea is typically incorporated in automated equipment washing systems developed by Stork, a reputable European textile equipment manufacturer. Thus, it is known that adequate screens and filters are available on the market for direct reuse of the dirty water. Clean water would be used only at the final stage of a washing cycle.

Solvent Cleaning. Judicious use of solvents is suggested for the most difficult cleaning jobs. This is an area in need of further investigation to determine when solvents can be applied more economically than water. One suggestion is to use a tub of solvent solution to soak the dirtiest equipment and break the emulsions before going to the water spray booths. An automated system is envisioned in which the equipment rotates through a solvent-filled trough and upward through an intense water spray, using dirty water initially and finishing with clean water. This is similar to an automated spray cleaning system for squeegees at the company's other nearby mill. Care would need to be taken to prevent air pollution from volatilization of solvents.

Manufacturing Changes. An important final note is that roller print technology can be supplemented by screen print technology. As stated earlier, screens and the associated aqueous solutions used in color formulations are more easily cleaned. If any of the mill's printing is converted from roller to screen, water use reduction is likely to accompany such a conversion.

Coagulation/Flotation for Water Recycle

A discussion of coagulation/flotation and its applicability in the textile industry is found in Volume 1. The technical feasibility of this technology has been established at several full-scale installations that reuse the clarified effluent of DAF in their print and color shops. Although Mill W-3 does not now reuse the clarified effluent in the print & color shop, it is suspected that it may be of adequate quality for reuse as is, or that improvements in the operation of the DAF system will yield adequate quality for reuse.

Performance of Existing DAF System. Table III-4 shows that the existing system encounters difficulties in solids removal, though it performs adequately for turbidity and color removal. Some of the coagulated floc particles may be scoured from the bottom of the float layer, because investigation showed that the float solids layer was up to 4 feet thick.

Other operating problems that may contribute to the solids removal problem are 1) inadequate dilution and mixing of polymer with the waste; 2) lack of rapid mix and flocculation facilities; and 3) lack of pH control.

Mill personnel state that the clarified effluent may be of adequate quality for reuse, despite the solids problem. Even with improved solids removal, there is a need for screening and lint filtration to avoid clogging of pumps, machinery and hose nozzles.

Mill personnel feel that the level of phenols and metals in the effluent should not be an obstacle to reuse as equipment cleaning water, though a period of testing is advisable to identify the possibility for damage to equipment or fabrics through contact with the equipment.

The residual color is typically a light amber, and testing of the wastewater for reuse should consider potential problems from the amber color.

Bench Scale Results. A bench scale test of coagulation with ferric chloride and the polymer used by Mill W-3 was conducted as a check on coagulant type and dosage. The optimum ferric chloride dose was about 600 mg/l, similar to the mill, and the polymer dose was about 5 mg/l, somewhat less than the 20 mg/l used at the mill. Mill personnel state that they feel the polymer feed system needs improvement to allow for better in-line mixing, perhaps by providing more injection points. They concur that the polymer dose is too high, so that the 5 mg/l dose appears reasonable.

Revised System. The revised DAF system described earlier and illustrated in Figure III-2, allows for coagulant and polymer mixing, flocculation, and pH control. These improvements coupled with water reduction and solids removal improvements in the DAF clarifier are expected to produce a clearer effluent adequate for reuse in equipment cleaning. Equipment manufacturers such as Stork of Europe have been incorporating efficient screens and lint filters in much of their automated equipment cleaning machinery, so that clogging of nozzles at the point of reuse will be prevented.

TECHNICAL DESIGN CRITERIA

Design criteria of the revised system with water reduction and reuse incorporated are summarized below:

Design flow:	127,000 gpd, 80-90 gpm
Equalization Volume:	0.3 million gallons
Type & Dosage of Coagulants:	600 mg/l $FeCl_3$ 5 mg/l polymer
Mixing Facility:	Rapid Mix - 1-2 minutes 200 gallons capacity; $Gt=1 \times 10^4$
Flocculation Facility:	$Gt = 0.5 \times 10^4$
pH Control:	Optional; achieved with $FeCl_3$ dose.

Type & Size of DAF Unit:	Circular; 16 foot diameter
Typical Solids Loading:	0.16 lb/sq ft./hr.
Hydraulic Loading:	0.68 gpm/sq. ft.
Air to Solids Ratio:	0.01 to 0.02
Air Pressure:	40 psig
Recycle Ratio:	50%

ECONOMIC FEASIBILITY

Flow Reduction and Direct Reuse Measures

There are few tangible costs associated with water reduction measures. Many of the measures involve improved housekeeping procedures and employee incentives and education; wastewater savings can be estimated on the basis of $0.43/1,000 gallons. With the projected reduction of 63,000 gpd, a wastewater savings of about $6,800 per year would be realized. It is estimated that $5,000 per year in miscellaneous costs could be incurred for training and housekeeping measures.

Localized sumps for direct reuse would incur costs for construction, installation of piping, pumps, and filters, and operation and maintenance of pumps and filters. It is expected that capital (installed) costs for a direct reuse sump would generally not exceed $4,000, and O&M costs would not exceed $1,000 per year. An area with potential for direct reuse is the drum washer. If 25,000 gpd were reused, wastewater savings of about $2,700 per year would be expected. Thus, the approximate payback for this example would be $4,000/ $1,700/yr = 2.4 years.

Coagulation/Flotation

This discussion looks at the economics of providing coagulation/flotation facilities in two ways: 1) no facilities currently in place, and 2) upgrading current facilities.

The benefits, costs, and paybacks of recycle/reuse for the print and color shop are presented in Table III-6. The basis for the development of cost and savings estimates is as follows:

TABLE III-6

ECONOMICS OF PRINT AND COLOR SHOP WASTEWATER RECYCLE/REUSE

	Water Reduction Only	Coagulation/ Flotation with Recycle		Total	
		1*	2*	1*	2*
Benefits					
Wastewater Savings, gpd	63,000	100,000	100,000	163,000	163,000
$/yr	$6,800	$10,800	$10,800	$17,600	$17,600
BOD Surcharge Savings, $/yr	--- (insignificant)	50,000	10,800	50,000	10,800
Total Savings	$6,800	$61,000	$22,000	$67,800	$28,800
Costs					
Capital					
Coagulation		80,000	80,000		
Flotation		75,000	--		
Equalization		70,000	--		
Pumps		15,000	6,000		
Storage		10,000	10,000		
Piping		30,000	15,000		
Filters		5,000	5,000		
Electrical		43,000	17,000		
Engineering		14,000	6,000		
Contingency		34,000	14,000		
Total Capital	Minimal	376,000	153,000		
Annual					
Coagulation		30,000	(40,000)		
Flotation		25,000	--		
Equalization		1,000	--		
Pumping		500	300		
Sludge Hauling		10,000	--		
Miscellaneous	5,000	14,000	12,000		
Total Annual	5,000	80,500	(27,700)	85,500	(22,750)
Payback Period	Immediate	no payback	3.1 years	no payback	3.0 years

* Note that 1 represents analysis assuming no facilities in place; 2 is analysis for facility upgrading.

Wastewater discharge savings of \$0.43/1,000 gallons

BOD surcharge savings based on \$0.13/lb for concentrations greater than 100 mg/l

Facilities operate 250 days per year

Electricity for pumping at \$0.0743/Kwhr

Coagulant dosage of 600 mg/l $FeCl_3$; 5 mg/l polymer

Cost of $FeCl_3$ = \$0.57/gallon, 3.5 lb/gallon

Cost of polymer = \$3.39/lb

Sludge hauling costs = \$10,000/yr based on current mill data

Capital costs are estimated in 1982 dollars on the basis of previous studies and discussed in Volume 1.

Table III-6 illustrates the promising economic potential for recycle of print wastewater in the case of upgrading the existing facilities. The two- to three-year payback period is reasonable and is even lower if coagulation facilities are not added. Upgrading the existing operation provides substantial benefits in terms of decreased coagulation costs in addition to the wastewater and BOD surcharge savings, and these additional benefits make the upgrading for recycle economically attractive. The savings from decreased wastewater and BOD discharge alone do not provide adequate economic incentive.

The construction of a complete new coagulation/flotation system is not economically feasible because no reasonable payback period is expected. Wastewater and BOD savings do not provide adequate savings to offset the capital costs and the fairly high annual costs for coagulation and flotation at this mill.

ENVIRONMENTAL EFFECTS

By examination of Tables I-3 and III-4, it is evident that the coagulation/flotation system effects a significant removal of BOD, COD, and phenolics. It is expected that improvements in treatment system operation would lead to more effective removal of TSS. Turbidity and color are vastly improved by means of the coagulation/flotation system. Iron, manganese, and chlorides show an increase because of the addition of ferric chloride as a coagulant.

Recycle of coagulation/flotation wastewater enables a further reduction of pollutant discharge by keeping the resultant pollutant load within the mill.

Water reduction measures are not expected to affect pollutant loads but will lead to decreased wastewater discharge.

Direct reuse sumps would decrease the overall loads depending on the amount of pollutants typically discharged from the particular area, such as drum washing, box and brush washing, and floor washing.

CONCLUSIONS

- Upgrading existing coagulation/flotation facilities and improving operations will enable recycle of treated wastewater for reuse in the print and color shop. Reduction in wastewater and BOD discharge plus savings in coagulant addition make the option economically attractive. Pilot plant work should be conducted to establish the need for rapid mix and flocculation facilities, and the effects of improved polymer mixing and solids handling should be investigated.
- The capital and annual costs for coagulation/flotation at this mill are not offset by wastewater and BOD discharge savings alone. However, lower coagulant dosages may make the technology economically attractive at other mills.
- Improved housekeeping procedures, conservation education and incentives, and direct reuse are expected to lead to a 33 percent wastewater discharge reduction, and the savings are economically attractive. Capital costs should be fairly minimal.
- Treated wastewater from coagulation/flotation should be tested to assure that equipment can be effectively washed without damage and that clogging of nozzles on hoses and other equipment can be avoided by in-line filtration.

SECTION IV
SOAPHOUSE WASTEWATER

DESCRIPTION OF MANUFACTURING PROCESSES

All fabrics are subjected to the soaping process subsequent to printing and ageing in order to remove excess print & color formulations and any chemicals applied during ageing, such as acetic acid. As described in the introduction, the soaphouse consists of a variety of ranges, including a horizontal laced open width soaper, a rope soaper, and a backgrey washer. The mill plans to use the rope soaper sparingly in the near future when another open width soaper comes on-line.*

The open width soaper is illustrated in its two modes of operation in Figure IV-1, and the backgrey washer is illustrated in Figure IV-2.

The rope soaper is illustrated in Figure IV-3 in order to consider the effects of its abandonment on water and energy use.*

Water and Chemical Use

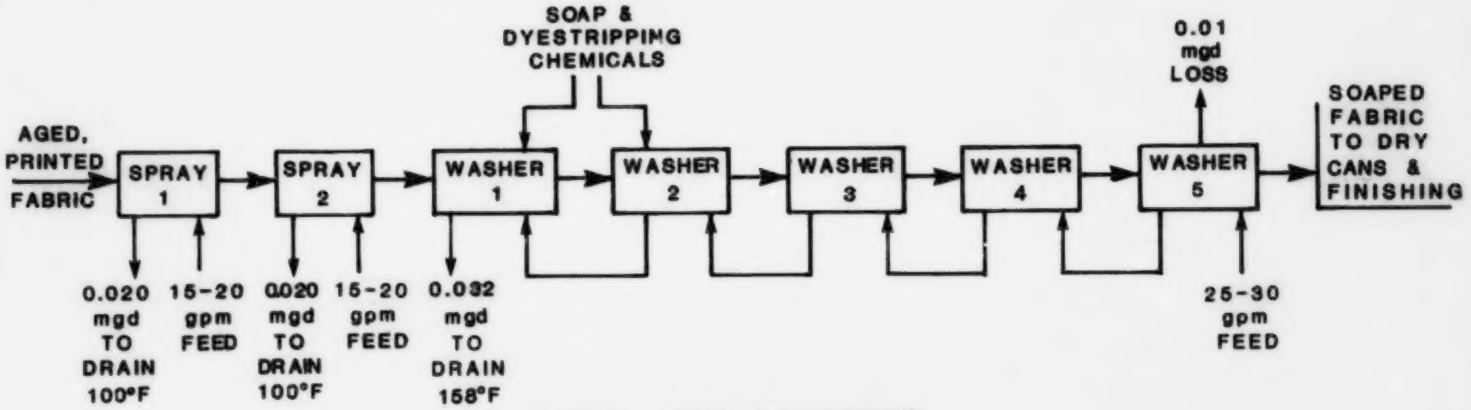
Open Width Soaper. The schematic diagram in Figure IV-1 shows that about 100,000 gpd are used at the open width soaper, with about 75,000 to 80,000 gpd used for Mode 1 (complete counterflow) and 20,000 to 25,000 gpd used for Mode 2 (partial counterflow). The range processes about 50,000 pounds of fabric per day, resulting in an average water use of about 2 gallons per lb. The wastewater flow of 90,000 gpd is discharged with other soaphouse water directly to the sewer. The flow from the washers is discharged at about 158°F, while the flow from the sprays is discharged at about 100°F.

The chemicals added to the washers are soap and proprietary dyestripping chemicals. Unfixed dyes and pigments are removed physically in the spray boxes, and others are removed chemically and thermally in the wash boxes.

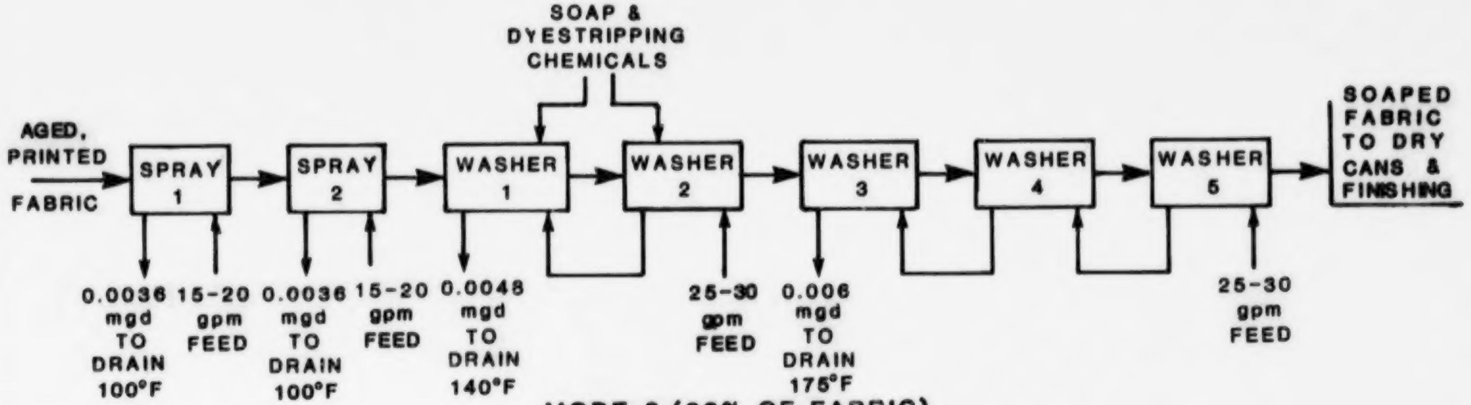
Backgrey Washer. Figure IV-2 shows that about 60,000 gpd are used at the backgrey washer to process about 130,000 yards (37,000 pounds)

---

* Since the time of Phase II investigations, the rope soaper has been abandoned and replaced by a new open-width soaper.


SOAP &
DYESTRIPPING
CHEMICALS
0.01
mgd
LOSS
AGED,
PRINTED
FABRIC
SPRAY 1
SPRAY 2
WASHER 1
WASHER 2
WASHER 3
WASHER 4
WASHER 5
SOAPED
FABRIC
TO DRY
CANS &
FINISHING
0.020 mgd TO DRAIN 100°F
15-20 gpm FEED
0.020 mgd TO DRAIN 100°F
15-20 gpm FEED
0.032 mgd TO DRAIN 158°F
25-30 gpm FEED

MODE 1 (80% OF FABRIC)


SOAP &
DYESTRIPPING
CHEMICALS
AGED,
PRINTED
FABRIC
SPRAY 1
SPRAY 2
WASHER 1
WASHER 2
WASHER 3
WASHER 4
WASHER 5
SOAPED
FABRIC
TO DRY
CANS &
FINISHING
0.0036 mgd TO DRAIN 100°F
15-20 gpm FEED
0.0036 mgd TO DRAIN 100°F
15-20 gpm FEED
0.0048 mgd TO DRAIN 140°F
25-30 gpm FEED
0.006 mgd TO DRAIN 175°F
25-30 gpm FEED

MODE 2 (20% OF FABRIC)

FIGURE IV -1
SCHEMATIC DIAGRAM
HORIZONTAL OPEN WIDTH SOAPER
MODES 1 & 2
(AT TIME OF FIELD INVESTIGATION)

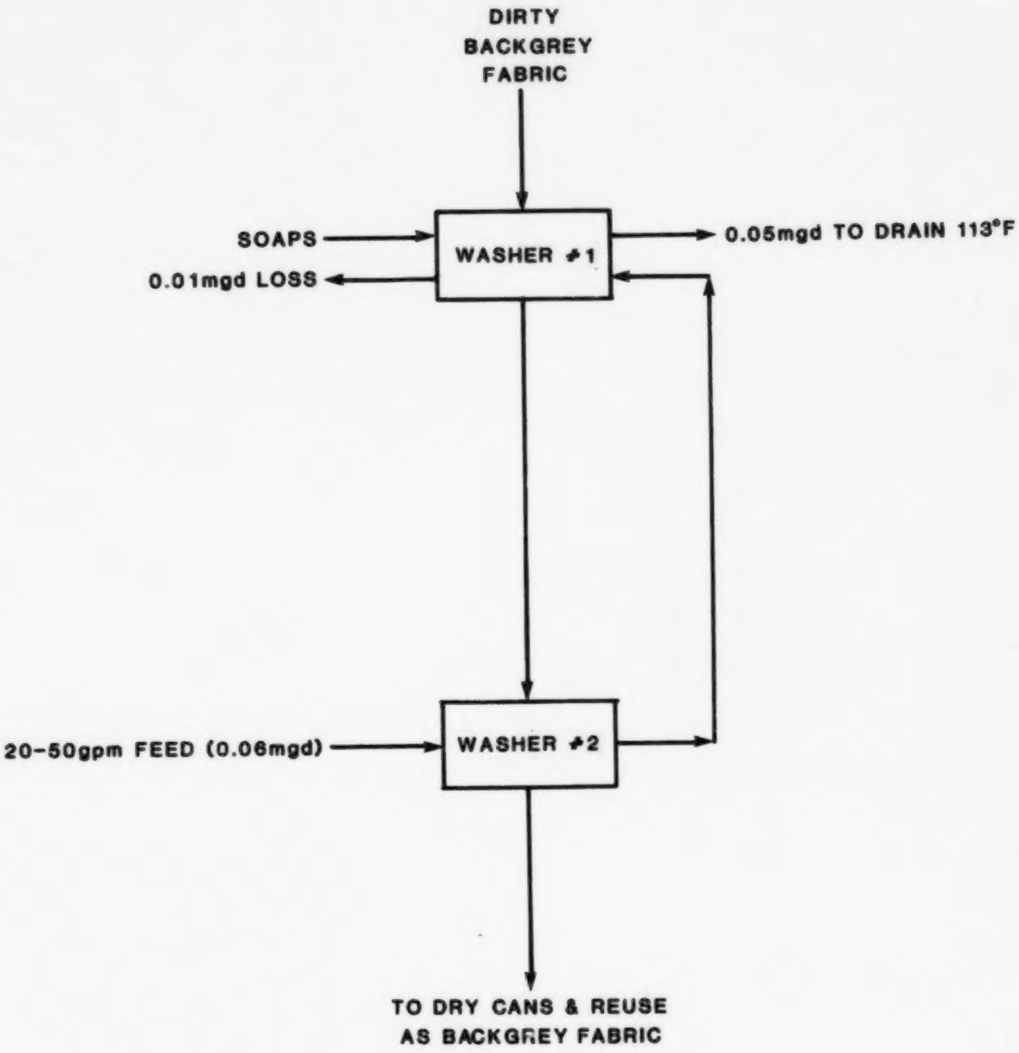

DIRTY BACKGREY FABRIC
SOAPS
WASHER #1
0.05mgd TO DRAIN 113°F
0.01mgd LOSS
20-50gpm FEED (0.06mgd)
WASHER #2
TO DRY CANS & REUSE AS BACKGREY FABRIC

FIGURE IV -2
SCHEMATIC DIAGRAM
BACKGREY WASHER

per day of cotton backgrey fabrics. This results in an average water use of 1.6 gallons per lb of fabric. The wastewater flow of about 50,000 gpd is discharged directly to drain at a temperature of about 113°F. Soaps and detergents are added to assist in removing excess color from the fabric.

Rope Soaper.* Figure IV-3 shows that about 280,000 gpd were used at the rope soaper to process about 34,000 pounds of fabric per day, which resulted in an average water use of 8.2 gallons per lb of fabric. The wastewater flow of about 260,000 gpd was discharged at about 113°F directly to the sewer with other soaphouse wastewater. It is apparent that water use was excessive at this range, and observations showed that although counterflow piping was in place between Washer 3 and Washer 2, it was not used.

Soaps were added in the first two washers to remove excess dyes and pigments.

Wastewater Characterization

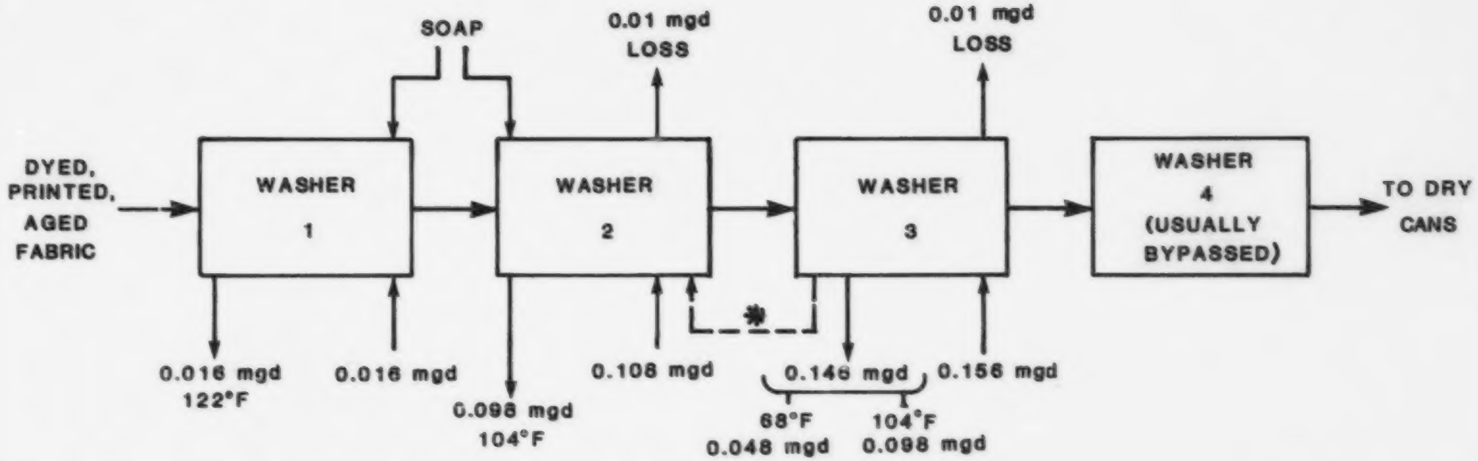
Open Width Soaper. Wastewater samples from the open width soaper were collected and analyzed, and the results are shown in Tables IV-1 and IV-2. The soaper contributes a relatively small percentage of the total mill organic and solids load (6.7 percent of the BOD, 8.2 percent of the COD, 2.3 percent of the TSS), indicating that relatively small amounts of the dyes and pigments are removed. However, the concentrations of BOD and COD are noteworthy in their range from 150 mg/l at Washer 1 in Mode 1 to 3870 mg/l at Spray 1 in Mode 1. The level of pollutants generally appears to be greater in Mode 1 than in Mode 2, but this likely reflects the fact that Mode 1 predominates and processes a larger variety of fabrics and color formulations.

There is no clear trend as to the location of the maximum removal of excess color formulations, except that it appears more color is found in the washer wastewater than in the spray wastewater.

The levels of sodium and chromium are noteworthy in the Mode 1 wastewater and indicate that color formulations are removed at all locations.

---

* The rope soaper has been abandoned since Phase II investigations and replaced by a new open width soaper.


DYED, PRINTED, AGED FABRIC
WASHER 1
SOAP
WASHER 2
0.01 mgd LOSS
WASHER 3
0.01 mgd LOSS
WASHER 4 (USUALLY BYPASSED)
TO DRY CANS
0.016 mgd 122°F
0.016 mgd
0.098 mgd 104°F
0.108 mgd
*
0.146 mgd
68°F 0.048 mgd
104°F 0.098 mgd
0.156 mgd

* NOTE: COUNTERFLOW CAPABILITY NOT USED

FIGURE IV -3
SCHEMATIC DIAGRAM
ROPE SOAPER

TABLE IV-1
OPEN WIDTH SOAPER
MODE 1

	Concentration, mg/l					
	Spray 1		Spray 2		Wash 1	
Alkalinity (as $CACO_3$)	660	410	340	160	210	120
MBAS (as LAS)	5.5	6.5	6.7	6.2	20	22
BOD	1,650	1,450	950	550	153	700
COD	3,870	3,280	2,220	1,550	2,180	1,780
TDS	6,200	3,200	3,370	1,400	1,860	880
TSS	74	52	55	56	130	80
Chloride	1,120	-	475	-	180	-
Oil & Grease	31	450	140	16	44	150
Phenolics	0.37	0.24	0.21	0.16	1.76	0.53
Turbidity (NTU)	30	26	2.3	60	0.26	3.8
Color (ADMI)	3,510	376	4,020	395	10,800	2,920
Hardness (as $CaCO_3$)	97	69	48	40	48	61
Sodium	1,750	1,510	1,650	440	470	290
Chromium	5.7	16	3.3	9.0	20	17
Copper	1.1	0.83	0.14	0.71	0.25	0.36
Iron	0.56	0.58	0.45	0.54	0.64	0.62
Manganese	0.27	0.11	0.17	<0.1	0.18	<0.1
Zinc	0.11	0.12	<0.1	<0.1	1.2	0.79
pH (SU)	5.9	5.8	5.9	5.9	6.3	6.1
Temperature (°F)	99	97	100	97	158	158

Source: Wastewater samples taken May 17 to 21, 1982.

TABLE IV-2
OPEN WIDTH SOAPER
MODE 2

	Concentration, mg/l			
	Spray 1	Spray 2	Wash 1	Wash 3
Alkalinity (as $CaCO_3$)	190	52	110	500
MBAS (as LAS)	6.7	1.6	24	9.9
BOD	440	220	560	500
COD	1,710	600	1,450	1,590
TDS	1,900	650	1,000	760
TSS	46	40	64	240
Oil & Grease	67	14	24	100
Phenolics	0.18	0.12	0.41	0.28
Turbidity (NTU)	5.3	5.3	12	1.4
Color (ADMI)	1,600	177	2,700	5,780
Hardness (as $CaCO_3$)	50	28	24	32
Sodium	480	180	300	440
Chromium	0.15	<0.1	1.8	2.0
Copper	0.7	0.22	0.27	0.34
Iron	0.53	0.40	0.63	1.9
Manganese	0.7	0.27	0.40	0.13
Zinc	0.21	<0.1	0.78	0.92
Temperature (°F)	95	100	140	175

Source: Wastewater samples taken May 17 to 21, 1982.

The highest levels of surfactants, measured as MBAS or LAS, are found in Washer 1 at 24 mg/l LAS.

Backgrey Washer. Wastewater samples from the backgrey washer were collected and analyzed, and the results are shown in Table IV-3. The backgrey washer produces a highly colored wastewater with a significant amount of phenolics and chromium that have an effect on the final mill discharge. The organics and solids loads are fairly small (3.2 percent of total BOD, 4.2 percent of total COD, 2.6 percent of total TSS).

The data indicate that excess color formulation is removed and that the levels on the fabric vary widely.

Rope Soaper.* Wastewater samples from the rope soaper were collected and analyzed, and the results are shown in Table IV-4. This table and Table I-3 show that the rope soaper contributed less than 1 percent of the BOD, COD, and TSS to the mill's effluent despite contributing nearly 20 percent of the total effluent flow.

The wastewater was more highly colored (5570 ADMI units) in Washer 1 than in Washer 2, and it generally appeared that Washers 2 and 3 wastewater could have been counterflowed completely without a serious effect on the soaping operation. The data provided further evidence that water use was excessive here, because a great deal of contamination was not observed. This is discussed further under recycle/reuse methods.

DESCRIPTION OF APPLICABLE RECYCLE/REUSE METHODS

The methods for wastewater recycle/reuse in the soaphouse are discussed under the following headings:

- Flow reduction
- Direct reuse and heat recovery

Flow Reduction

The primary means of flow reduction is by the manufacturing change from rope to open width soaping. The open width soapers are more

---

* The rope soaper has been abandoned since Phase II investigations and has been replaced by a new open width soaper.

TABLE IV-3
BACKGREY WASHER

	Concentration, mg/l		
Alkalinity (as $CaCO_3$)	470	300	87
MBAS (as LAS)	13	9.9	4.6
BOD	500	1,000	480
COD	2,310	1,470	2,300
TDS	1,550	1,800	420
TSS	190	280	70
Chloride	80	-	-
Oil & Grease	120	220	24
Phenolics	1.93	8.56	13.26
Turbidity (NTU)	0.4	9	20
Color (ADMI)	2,160	12,800	2,580
Hardness (as $CACO_3$)	52	61	73
Sodium	490	500	540
Chromium	18	3.8	29
Copper	2.0	3.0	0.96
Lead	2.6	1.3	0.72
Manganese	0.32	0.24	0.13
Zinc	0.58	0.31	0.17
pH (SU)	9.0	9.6	9.4
Temperature (°F)	113	115	109

Source: Wastewater samples taken May 17 to 21, 1982.

TABLE IV-4
ROPE SOAPER*

	Concentration, mg/l	
	Washer 1	Washer 2
Alkalinity (as $CaCO_3$)	260	18
MBAS (as LAS)	0.013	0.074
BOD	180	36
COD	600	42
TDS	1,000	78
TSS	25	8
Chloride	-	-
Oil & Grease	62	500
Phenolics	0.049	0.01
Turbidity (NTU)	2.6	3.7
Color (ADMI)	5,570	370
Hardness (as $CaCO_3$)	28	8.1
Sodium	280	25
Chromium	< 0.1	< 0.1
Copper	< 0.1	< 0.1
Iron	0.35	0.34
Manganese	< 0.1	< 0.1
Zinc	< 0.1	< 0.1
pH (SU)	9.3	8.5
Temperature (°F)	122	104

* Note that this soaper has been removed from operation and replaced by a second open width soaper during Fall 1982.

Source: Wastewater samples taken May 17 to 21, 1982.

efficient in water and energy use. The water use reduction achieved by this change is from 380,000 gpd for the current soaping operation (rope and open width) to 200,000 gpd for dual open width soapers. See Figure IV-4 for an illustration of the plan for the soaphouse.

Open Width Soaper. Flow reduction at the open width soaper is not projected, because the most efficient mode of operation has not been identified by the mill, and highly variable washing requirements are encountered. This is discussed further under Technical Feasibility.

Backgrey Washer. Flow reduction is not projected because of the highly variable requirements for washing at this range.

Direct Reuse and Heat Recovery

The planned reuse and heat recovery scheme is illustrated in Figure IV-4. About 60,000 gpd from the 180,000 gpd discharged by the two open width soapers will be reused directly for washing the backgrey fabrics.

Wastewater from the soapers and backgrey washer will flow to a recovery pit, from which it will be pumped to the backgrey washer for reuse or the heat exchanger to preheat incoming feed water. The hot water from the washers (158°F) will be segregated from the cold water of the sprays (95-105°F), so that about half the total wastewater from the soapers (0.09 mgd) flows to the heat exchanger, and the remainder flows to either the backgrey washer or directly to drain.

A total of about 170,000 gpd will be discharged, consisting of 90,000 gpd from the heat exchanger, 30,000 gpd from the recovery pit, and 50,000 gpd from the backgrey washer.

TECHNICAL FEASIBILITY

Flow Reduction

Rope Soaper.* The discussion of water use and wastewater characteristics explains the need and potential for flow reduction at this range. A water use of 8 gallons per pound of fabric was much

---

* The rope soaper has been abandoned since Phase II investigations and has been replaced by a new open width soaper.

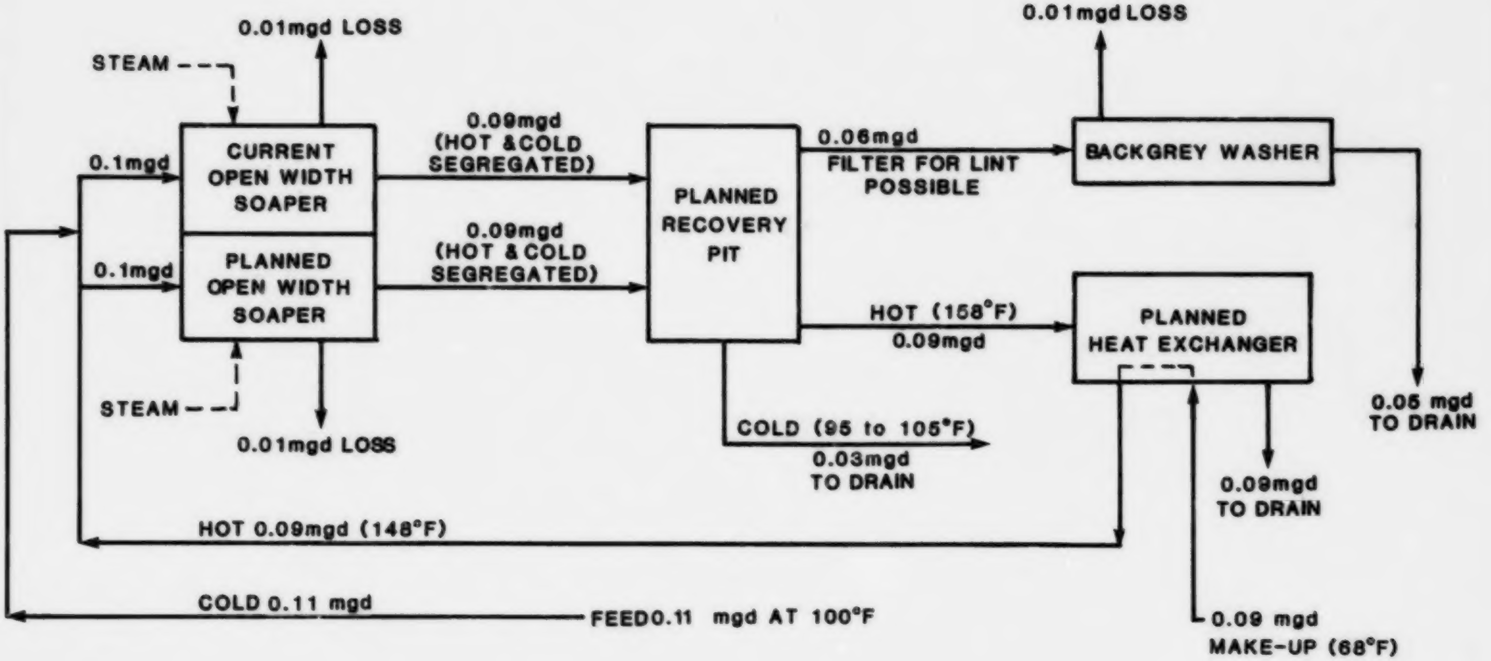

STEAM
0.01mgd LOSS
0.1mgd
CURRENT OPEN WIDTH SOAPER
0.1mgd
PLANNED OPEN WIDTH SOAPER
STEAM
0.01mgd LOSS
0.09mgd (HOT &COLD SEGREGATED)
0.09mgd (HOT & COLD SEGREGATED)
PLANNED RECOVERY PIT
0.06mgd
FILTER FOR LINT POSSIBLE
HOT (158°F)
0.09mgd
COLD (95 to 105°F)
0.03mgd TO DRAIN
0.01mgd LOSS
BACKGREY WASHER
0.05 mgd TO DRAIN
PLANNED HEAT EXCHANGER
0.09mgd TO DRAIN
HOT 0.09mgd (148°F)
COLD 0.11 mgd
FEED0.11 mgd AT 100°F
0.09 mgd MAKE-UP (68°F)

FIGURE IV -4
SOAPHOUSE
PLANNED REUSE AND HEAT RECOVERY

greater than the 2 gallons per pound used at the open width soaper, and the relatively low concentrations of most pollutant parameters indicate that excessive dilution was occurring. The relatively clean effluent from washer 2 indicated that it had the potential for direct reuse at washer 1 and that the effluent of washer 3 also had the potential for reuse by a counterflow arrangement. Piping was in place for counterflow from washer 3 to washer 2, but mill personnel stated the counterflow mode was not used.

Open Width Soaper. The potential for water reduction is not apparent from water use and wastewater data. The optimum mode of operation has not been identified by the mill. It is expected that it will operate in different modes to accomodate the variations in washing requirements for the incoming fabrics and color formulations.

Backgrey Washer. The potential for water reduction is again not apparent. The requirements for washing are too highly variable to plan a definite reduction.

Direct Reuse and Heat Recovery

The mill has determined that the quality of the water used for washing backgrey fabrics is not critical, because they aim only to remove gross deposits of excess color formulation. A thoroughly clean fabric is not necessary, and color is not an important parameter for these fabrics.

The segregated hot discharge from the soapers is expected to have a temperature of 158°F; and this provides the potential for heat recovery in a heat exchanger system. The heat exchanger technology is well established throughout industry; thus, discussion of its technical feasibility is not needed. The economics of its operation are discussed under Economic Feasibility.

Notes on Other Reuse or Treatment/Recycle

The potential for direct reuse of soaphouse wastewater in other mill processes is not apparent, because the color levels are typically too high even for equipment cleaning in the print room. It should also be noted that the soaphouse wastewater is too dilute in terms of a colloidal suspension to consider treatment such as coagulation/flotation. A bench scale coagulation test showed that coagulation was not effective for the dilute suspension normally encountered in the soaphouse wastewater, even though similar constituents from color formulations enter the wastewater. Other means of treatment were not considered because of the dilute nature of the colloidal suspension, and no effective treatment has been documented to date.

Mill personnel noted that occasionally white fabrics are processed on the soaper, and the spray portion of the soaper may have the potential for reuse in the print room for equipment cleaning. This is intermittent and difficult to plan, so it is not included in the plans here.

TECHNICAL DESIGN CRITERIA

The heat exchange system is projected to include a counterflow plate and frame arrangement with the following characteristics:

Wastewater Feed	90,000 gpd, 158°F
Fresh Water Feed	90,000 gpd, 68°F
Fresh Water Output	90,000 gpd, 148°F
Wastewater Output	90,000 gpd, 78°F
Pressure Drop	6 psig

Model: Tranter UX-216, UP-111, 304 stainless steel*

ECONOMIC FEASIBILITY

The benefits, costs, and payback of recycle/reuse/heat recovery of soaphouse wastewater are presented in Table IV-5. The basis for the development of cost and savings estimates is as follows:

- Wastewater discharge savings of $0.43/1,000 gallons
- Energy savings of $5.14 per million BTU
- Soaphouse operates 250 days/year
- Counterflow heat exchanger is projected to raise incoming water temperature from 68°F to 148°F while soaper wastewater from washers drops from 158°F to 78°F.
- Electricity for pumping at $0.0743/Kwhr.
- Capital costs are estimated in 1982 dollars on the basis of vendor quotes and previous studies.

---

* Note that a complete evaluation of models has not been conducted; the model mentioned is one of many possible models.

TABLE IV-5
ECONOMICS OF SOAPHOUSE WASTEWATER RECYCLE/REUSE

Benefits	
Water Savings (230,000 gpd)	$ 25,000
Energy Savings	113,000
BOD Savings	Negligible
Total Savings	$138,000
Costs	
Capital	
New Soaper	$650,000
Heat Exchanger	7,000
Lint Filters	5,000
Piping	4,500
Pumps	5,000
Storage	3,000
Electrical	4,000
Engineering	1,000
Contingency	3,000
Total Capital	$683,000
Annual*	
O&M of Heat Exchanger	$ 1,200
Pumping	200
Miscellaneous	1,000
Total Annual	$ 2,400

Payback Period* = $683,000/$135,000 = 5.0 years

* Benefit of increased productivity due to new soaper not included in this analysis. O&M costs of new soaper assumed equal to O&M costs of old soaper.

Table IV-5 illustrates the potential for substantial savings in the soaphouse, primarily due to heat recovery. The payback period of five years does not include the benefits of increased productivity due to the new soaper.

The mill continues to study methods to optimize the soaping operation in the open width soapers, particularly in terms of chemical, energy, and water use. Further energy and water use benefits may result from other process changes. As stated earlier, the rope soaper has been abandoned, so the economic analysis is based on the elimination of the rope soaper.

ENVIRONMENTAL EFFECTS

Pollutant discharge is not expected to change significantly as a result of recycle/reuse and manufacturing changes in the soaphouse, although the wastewater discharge decreases from 0.4 mgd to 0.13 mgd. Table I-3 illustrates that the soaphouse pollutant loadings are a small percentage of the total, and the projected changes in the soaphouse are not expected to change the soaphouse pollutant discharge.

CONCLUSIONS

- The planned changes in the soaphouse for water reuse/reduction and heat recovery are promising and should result in substantial economic savings.
- Effects on pollutant discharge are expected to be negligible.
- Treatment for reuse in other areas of the mill is not promising because of the dilute nature of the wastewater.
- Optimization of open width soaper operation may lead to further water reduction and better potential for treatment and further reuse.

MILL SURVEY REPORT
MILL W-4
WOVEN FABRIC PREPARATION AND PRINTING

SUMMARY

Mill W-4, an integrated woven fabric finishing mill, conducts a variety of finishing processes that have been investigated for the potential applicability of wastewater recycle/reuse. Figure 1 illustrates the basic finishing processes, summarizes the findings of this investigation, and identifies further research needs. Table 1 illustrates the projected savings, costs, and paybacks associated with recycle/reuse options considered at this mill.

The most promising recycle/reuse options at this mill are: 1) reuse of the entire flow of water jet weaving wastewater at the looms and scour/desize washers; 2) dyebath reconstitution at two to four large dyeing machines; and 3) ultrafiltration for size recovery from the desize wastewater.

RECOMMENDATIONS

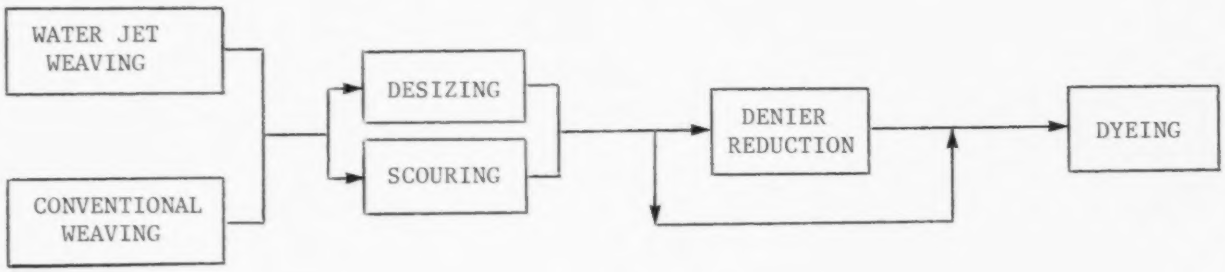
It is recommended that the following research needs be considered in future investigations:

Water Jet Weaving Wastewater - Reuse at Looms and Scour/Desize Washers

- A detailed investigation of piping requirements is needed to establish the capital costs more definitely.
- The effects of reused wastewater on the looms and fabrics must be evaluated to show that damage is not likely from oils in the recycled water.
- Pilot testing of in-line filters should be conducted to evaluate the ability to remove oils that may occasionally enter the wastewater.
- Housekeeping procedures around the looms should be studied and an employee education program developed to promote better housekeeping so as to reduce the entry of oils into the wastewater.

Dyebath Reconstitution

- A revised cooling/rinsing procedure needs to be developed and tested so that spent concentrated dyebaths can be stored


WATER JET WEAVING
CONVENTIONAL WEAVING
DESIZING
SCOURING
DENIER REDUCTION
DYEING

Technologies Evaluated	Feasibility		Data Needs
	Technical	Economic	
Water Jet Weaving			
Direct Reuse	feasible	promising	Acceptable oil content
Reuse in Desizing	feasible	not promising	--
Desizing			
Size Recovery	questionable	promising	Evaluate size degradation
Scouring			
Oil Recovery	feasible	not promising	--
Denier Reduction			
TPA Recovery	feasible	not promising	--
Dyeing			
Reconstitution	feasible	promising	Revised rinsing procedure
Decolorization (chlorine)	feasible	not promising	--

FIGURE 1

TABLE 1
SUMMARY OF ECONOMIC AND ENVIRONMENTAL BENEFITS OF VARIOUS RECYCLE SCHEMES

Recycle/Reuse Scheme	Annual Savings	Capital Cost	Payback (Years)	Flow Reduction		COD Reduction	
				gpd	% Total	lb/day	% Total
Ultrafiltration							
o Size Recovery	$217,000	$550,000	2.5	25,600	3	500	7
o Size Recovery & Oil Separation	$119,000	$1,072,000	9.0	88,000	12	1,100	16
Dyebath Reconstitution	$148,300	$ 65,000	0.4	26,400	4	1,120	16
Dyebath Oxidation/Reuse	$ 92,000	$430,000	4.7	216,000	29	1,600	23
Water Jet Weaving Water							
o Reuse at Looms & Washers	$ 35,200	$ 26,000	0.7	150,000	20	-	-
o Reuse at Washers Only	$ 7,800	$ 22,000	2.8	75,000	10	-	-
Terephthalic Acid Recovery	$ 40,000	$100,000	2.5	1,200	1	310	4

for reuse. The current overflow rinse procedure is not fully compatible with dyebath reuse.

- A convenient method for dyebath storage must be developed.
- Testing of reused dyebaths must be conducted to determine any adverse effects on dyeing quality. Sequencing of colors must be planned and tested for reuse.
- Actual chemical savings must be determined in reuse experiments.

Ultrafiltration for Size Recovery from Desize Wastewater

- The efficiency of the desizing operation and the effect of desizing on the chemical nature of the size must be investigated in detail.
- The effects of a two-stage desizing procedure with a hot water stage followed by an alkaline stage should be evaluated with regard to size removal, size degradation, and water and energy usage.
- Pilot-scale testing should be conducted to identify the optimum membrane type and configuration and to develop flux data. Capital costs can then be more clearly established.
- Recovered size should be tested for effects on weaving efficiency, desizing, and dyeing.

TABLE OF CONTENTS

Page

Summary. ii

Table of Contents. vi

I. INTRODUCTION. 1

Facility Description. 1

Manufacturing Processes 1

Overall Mass and Energy Balances. 4

Evaluation of Recycle/Reuse Technologies. 11

II. ULTRAFILTRATION OF DESIZING/SCOURING WASTEWATER. 12

Description of Manufacturing Process. 12

Description of Applicable Recycle/Reuse Methods . . . 16

Technical Feasibility 20

Technical Design Criteria 24

Economic Feasibility. 25

Environmental Effects 30

Conclusions 30

III. DYEBATH RECONSTITUTION 31

Description of Manufacturing Process. 31

Evaluation of Potential for Dyebath Reconstitution. . 32

Environmental Effects 40

Conclusions 40

IV. CHEMICAL OXIDATION OF DYE WASTEWATER 42

Description of Manufacturing Process. 42

Description of Applicable Recycle/Reuse Methods . . . 42

Technical Feasibility 45

Technical Design Criteria 46

Economic Feasibility. 46

Environmental Effects 50

Conclusions 50

TABLE OF CONTENTS (continued)

Page

V. REUSE OF WATER JET WEAVING WASTEWATER 51
Description of Manufacturing Process 51
Evaluation of the Potential for Reuse. 51
Environmental Effects. 59
Conclusions. 59

VI. RECOVERY OF TEREPHTHALIC ACID FROM DENIER REDUCTION WASTEWATER. 61
Description of Manufacturing Process and Applicable Recycle/Reuse Method. 61
Technical Feasibility. 61
Economic Feasibility 64
Environmental Effects. 65
Conclusions. 65

References. 66

Appendix A 67

SECTION I

INTRODUCTION

FACILITY DESCRIPTION

Mill W-4 is an integrated mill in the woven fabric finishing sector of the textile industry. The mill produces finished woven fabrics for wearing apparel. Total production averages 500,000 pounds per week. Currently, 60 to 70 percent of production consists of 100 percent polyester fabrics from filament polyester fibers. Of the remaining production, 15 to 20 percent consists of polyester/wool blends, 10 to 15 percent consists of polyester/cellulose (cotton or rayon) blends, and a small percentage consists of a variety of modified polyester blends.

MANUFACTURING PROCESSES

The mill performs both dry and wet operations to prepare and finish the incoming fibers. These operations are illustrated on the schematic in Figure I-1. Dry operations (greige mill operations) consist of slashing and weaving. Wet operations include scouring, desizing, and dyeing.

Slashing & Weaving

Greige mill operations consist of slashing and weaving. Approximately 30 percent of total greige production consists of goods that are sized with acrylic sizes. The remaining 70 percent is not sized.

Weaving is done on both water jet and dry looms. Approximately half the greige production at this mill (30 percent of total production) consists of fabrics woven on 164 water jet looms, with the other half (30 percent of total production) woven on 373 traditional dry looms. The remaining 40 percent of total greige production is woven on water jet looms at a nearby mill of the same parent company.

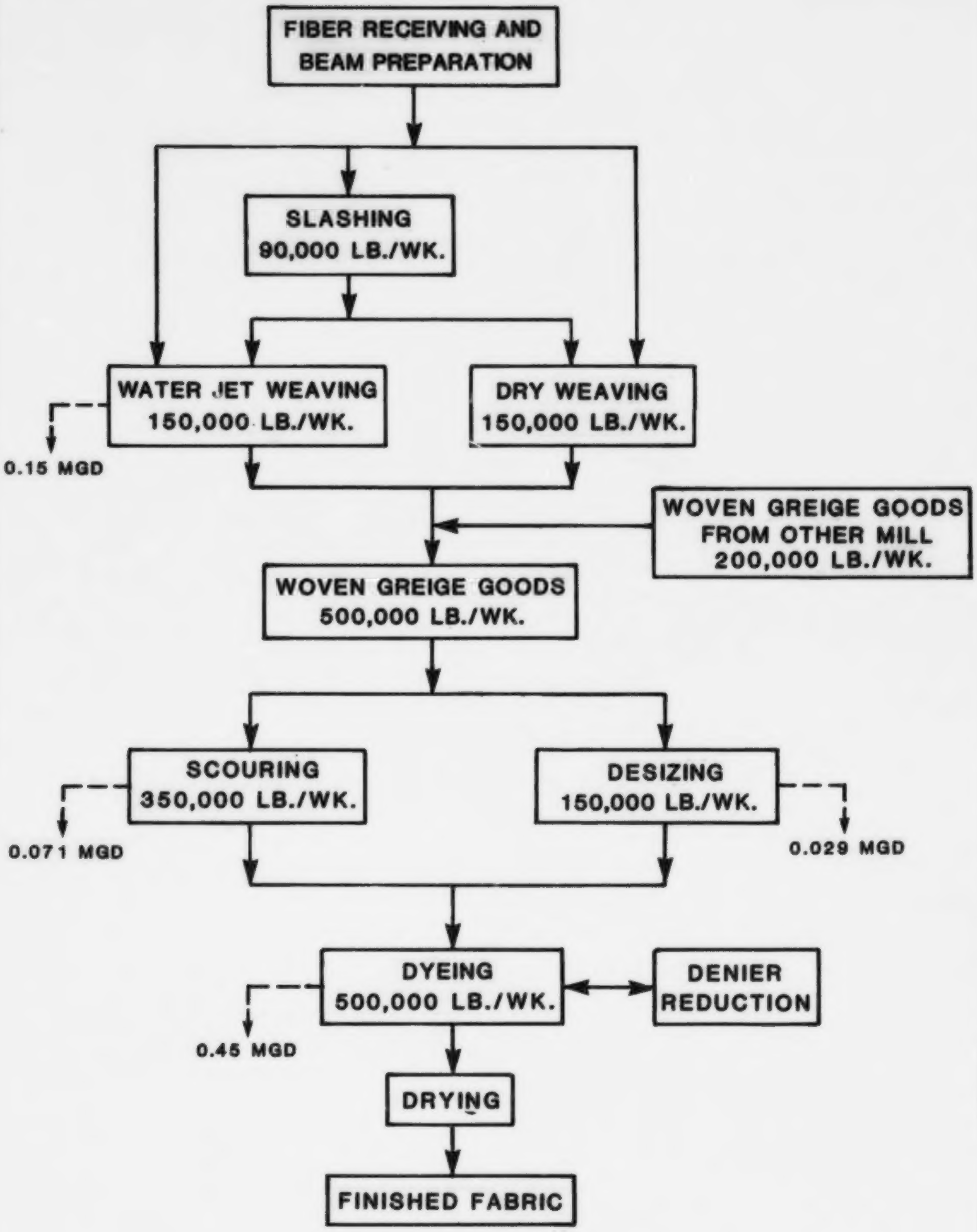

FIBER RECEIVING AND BEAM PREPARATION
SLASHING 90,000 LB./WK.
WATER JET WEAVING 150,000 LB./WK.
0.15 MGD
DRY WEAVING 150,000 LB./WK.
WOVEN GREIGE GOODS FROM OTHER MILL 200,000 LB./WK.
WOVEN GREIGE GOODS 500,000 LB./WK.
SCOURING 350,000 LB./WK.
0.071 MGD
DESIZING 150,000 LB./WK.
0.029 MGD
DYEING 500,000 LB./WK.
0.45 MGD
DENIER REDUCTION
DRYING
FINISHED FABRIC

FIGURE I-1. MANUFACTURING PROCESSES

Scouring and Desizing

The woven greige goods are scoured and/or desized on two continuous washers. As stated earlier, about 30 percent of total production contains size and is therefore desized. This percentage can vary with the seasons: more sized goods in lightweight fabrics for spring and summer; fewer sized goods in heavy weight fabrics for fall and winter.

All the desizing occurs on washer number 1, and the mill generally is able to schedule long runs of sized fabric in order to segregate the desizing operation from scouring on this washer. Washer number 2 performs only scouring. The chemical formulations and procedures used on these washers will be described in more detail in the discussion of recycle/reuse technologies.

Dyeing

Dyeing is performed in a batch mode on 19 pressure jet machines. Although dyeing at this mill involves a great variety of procedures, the mill focuses on disperse dyebaths for 100% polyester, which comprises 60 to 70 percent of production. The mill projects that they may be processing more blends in the future, but 100% polyester dyeing is expected to predominate.

The other five major dyeing procedures involve disperse/acid dyeing of polyester/wool blends (15 to 20 percent of production); disperse/direct dyeing of polyester/cellulose blends (10 to 15 percent of production); disperse/ basic dyeing of polyester/modified polyester blends; basic dyeing of modified polyester; and acid dyeing of wool (polyester/wool blends), with the polyester fiber left undyed.

A more detailed description of the dyeing machinery and procedures will be presented in the discussion of technologies for recycle/ reuse of dyebath wastewater.

All dyeing procedures are computer controlled. The mill's dyehouse office includes a computer system that displays the exact procedure being conducted at each dyeing mahcine, maintains a complete record of all the procedures used, and controls chemical additions, temperature, and cycle timing.

Drying

The mill dries the dyed fabric on three drying ranges. Drying is the final step in processing before inspection and packaging for shipment.

OVERALL MASS AND ENERGY BALANCES

Water Use and Characteristics

Total water use at the mill averages about 800,000 gpd. The major areas of water use at the mill are the processes of water jet weaving (150,000 gpd), scouring (78,000 gpd) and desizing (32,000 gpd), and dyeing (500,000 gpd). Minor water uses are for slashing, sanitary, boiler makeup, and general maintenance purposes (total 40,000 gpd). The overall water balance is illustrated on Figure I-2.

All the incoming water is purchased from the city. The portion used in water jet weaving and the boilers is softened at the mill from about 17 mg/l hardness to approximately 7.5 mg/l hardness, as $CaCO_3$. The rest of the mill generally uses the city water after treatment through pressure filters.

Table I-1 lists the quality of the general process and softened waters at the mill.

Wastewater Discharge and Characteristics

The major sources of wastewater discharge are essentially those named as the major water users. Some water is retained in the fabric after scouring, desizing, and dyeing. This is estimated to be 10 percent of the water used in these processes. See Figure I-2 for the wastewater balance.

The mill recovers energy from all hot wastewater discharges through a heat exchanger before final discharge. The heat exchange system is described in more detail below in the section on energy usage.

Wastewater samples were collected and analyzed from the major wet manufacturing processes of water jet weaving, scouring and desizing, and dyeing, and of the mill's final effluent. The results for conven-

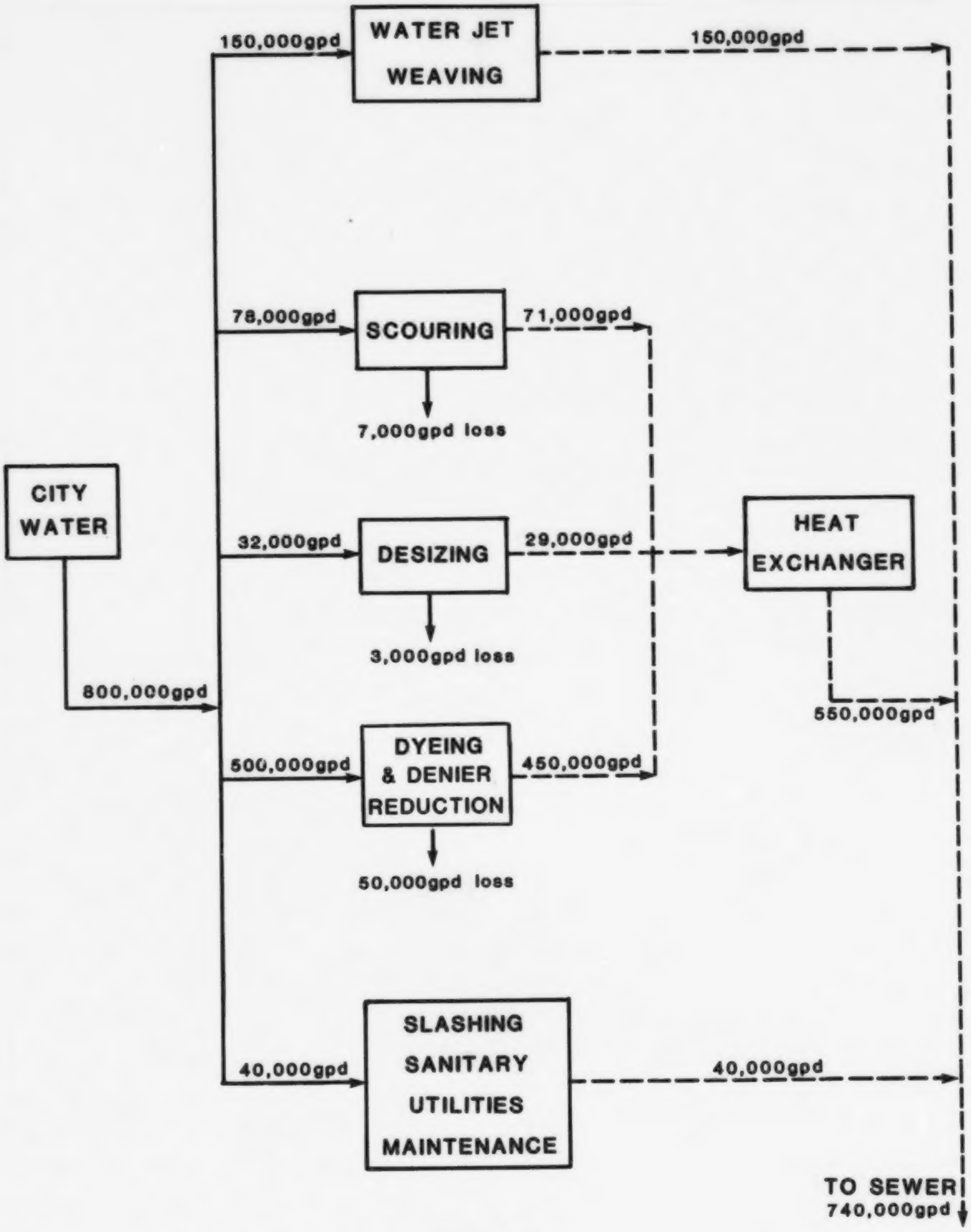

WATER JET WEAVING
150,000gpd
150,000gpd
SCOURING
78,000gpd
71,000gpd
7,000gpd loss
CITY WATER
800,000gpd
DESIZING
32,000gpd
29,000gpd
3,000gpd loss
HEAT EXCHANGER
550,000gpd
DYEING & DENIER REDUCTION
500,000gpd
450,000gpd
50,000gpd loss
SLASHING SANITARY UTILITIES MAINTENANCE
40,000gpd
40,000gpd
TO SEWER
740,000gpd

FIGURE I-2
WATER USE AND WASTEWATER DISCHARGE

TABLE I-1
WATER QUALITY FOR
PLANT WATER AND SOFTENED WATER

Constituent	Concentration (mg/l)*	
	Plant Water	Softened Water
pH	6.5	7.5
Color (ADMI)	6	6
COD	<1	16
TDS	200	220
Turbidity (NTU)	0.2	0.2
Phenolics	0.003	0.001
Chloride	9.8	9.6
Alkalinity	12	10
Calcium	4.0	1.2
Magnesium	1.7	1.1
Sodium	22	25
Chromium	< 0.2	< 0.2
Copper	< 0.2	< 0.2
Iron	< 0.1	0.55
Lead	< 0.2	< 0.2
Manganese	< 0.1	< 0.1
Nickel	< 0.1	< 0.1
Zinc	0.24	0.11
Temperature (°F)	50	54

* Sampled on March 15, 1982.

tional and nonconventional textile pollutants are presented in Table I-2 and discussed below. Table I-3 presents pollutant loadings for the major wastewater streams. Table I-4 presents results for all parameters analyzed in the final effluent. Other wastewater constituents that affect recycle are discussed below under the appropriate recycle technologies.

Energy Use and Types

The major sources for energy at the mill are natural gas and electricity. Natural gas, occasionally supplemented with fuel oil and propane, is used for space and water heating. Electricity is used for lighting and machinery operation throughout the mill. In 1981 the mill's average energy consumption was 28,000 million BTU per month from natural gas and 13,000 million BTU per month from electricity. Consumption varies with production and season, and the mill's records show that consumption in 1981 was about 18,000 BTU/lb, down from 27,000 BTU/lb in 1980.

It is interesting to note that water consumption per pound of product dropped from 24 gal/lb in 1980 to 17 gal/lb in 1981, showing the strong relationship between energy and water consumption.

An important factor in the mill's efforts to conserve energy is the use of a heat exchange system.

During a typical production period in March 1982, city water entered the heat exchanger at 50°F and was heated to 110°F by mill wastewater entering at 126°F. The wastewater left the exchanger at 66°F. The mill reported that the incoming city water is much warmer in the summer (77°F) thus enabling greater discharge temperatures for the plant water leaving the heat exchanger.

However, it must be noted that during the summer months, warm city water used in weaving must be chilled to about 60°F for operation of the water jet looms.

Energy use and savings for individual processes will be discussed in more detail in the discussion of recycle/reuse technologies.

TABLE I-2
WASTEWATER CHARACTERISTICS

Wastewater Source	Date	Concentrations (mg/l)				
		BOD	COD	TSS	Phenolics	pH (S.U.)
Water Jet Weaving	3/15/82	10	190	5	0.003	7.0
	3/16/82	14	170	2	0.120	6.6
	Avg.	12	180	4	0.061	--
Desizing	3/16/82	660	2,600	95	0.004	10.1
Scouring	3/15/82	100	1,200	3	0.057	8.2
	3/17/82	72	1,300	8	0.005	7.8
	Avg.	86	1,250	5	0.031	--
Denier Reduction	3/16/82	13,000	31,000	540	0.017	12.0
Dyeing	3/15/82	200	830	9	0.040	10.6
	3/16/82	300	2,000	33	0.790	5.1
	Avg.	250	1,415	21	0.415	--
Final Effluent	3/15/82	220	1,300	61	0.100	8.3
	3/16/82	190	1,100	94	0.015	7.2
	3/17/82	220	1,000	130	0.340	7.2
	Avg.	210	1,130	95	0.152	--

TABLE I-3
POLLUTANT LOADINGS

Source	Flow		BOD		COD		TSS		Phenolics	
	gal/day	% total	lb/day	% Total	lb/day	% Total	lb/day	% Total	lb/day	% Total
Water Jet Weaving	150,000	20	15	1	225	3	5	4	0.08	5
Desizing	29,000	4	160	12	630	9	23	20	0.001	0
Scouring	71,000	10	50	4	740	10	3	3	0.02	1
Dyeing	448,800	61	935	73	5,300	74	79	69	1.55	94
Denier Reduction	1,200	1	130	10	310	4	5	4	0.0002	0
Other*	40,000	5	10	--	(235)	--	475**	--	(0.71)	--
Final Effluent	740,000	100	1,300	100	6,970	100	590**	100	0.94	100

* Miscellaneous streams such as utilities, maintenance, etc., plus unaccounted for balance.

** Balance of suspended solids may be caused by precipitation of terephthalic acid from the denier reduction process caused by the lower pH of final effluent.

TABLE I-4
FINAL EFFLUENT

	Concentration, mg/l		
Alkalinity (as $CaCO_3$)	160	150	140
BOD - Total	220	190	220
BOD - Dissolved	150	150	160
COD	1,300	1,100	1,000
TS	610	620	960
TDS	670	600	730
TSS	61	94	130
Chloride	14	130	12
Oil & Grease	1,100	37	28
Phenolics	0.10	0.015	0.34
Turbidity (NTU)	125	170	140
Color (ADMI)	805	660	995
Calcium	2.4	2.3	2.6
Magnesium	1.8	1.8	1.7
Chromium	< 0.2	< 0.2	< 0.2
Copper	< 0.2	< 0.2	< 0.2
Lead	< 0.2	< 0.2	< 0.2
Nickel	< 0.1	< 0.1	< 0.1
Zinc	0.18	0.15	0.13
Sodium	400	160	170
Iron	0.95	1.1	0.96
Manganese	< 0.1	< 0.1	< 0.1
pH (S.U.)	8.3	7.2	7.2
Temperature (°F)	66	63	66

Source: Wastewater samples taken March 15 to 17, 1982.

EVALUATION OF RECYCLE/REUSE TECHNOLOGIES

The areas at Mill W-4 that were selected for study of recycle/reuse methods are the following:

- Desizing wastewater - ultrafiltration for size recovery and water recycle
- Scouring wastewater - ultrafiltration for oil separation and water recycle
- Dyebath reconstitution
- Dyeing wastewater - oxidation for decoloring
- Water jet weaving wastewater - direct reuse at scour/desize washers or treatment and reuse in water jet weaving
- Denier reduction wastewater - recovery of terephthalic acid

Each of these is considered in detail in the following sections.

SECTION II

ULTRAFILTRATION OF DESIZING/SCOURING WASTEWATER

DESCRIPTION OF MANUFACTURING PROCESS

Approximately 29 percent of the greige goods to be finished at this mill are sized with an acrylic size in preparation for weaving. The size is applied at 10 to 15 percent of the weight of the fabric and must be removed in the desizing operation to facilitate the dyeing operation. The remaining 71 percent of the greige goods do not contain size, but must still be scoured to remove oils, waxes, and other impurities on the fabric.

Currently the mill has two washers. All desizing is conducted on washer #1. Scouring of unsized goods also occurs on washer #1, and the mill states that these are the more "critical" goods. Scouring of unsized "non-critical" goods occurs on washer #2.

Water and Chemical Use

Flow schematics of the desizing and scouring operations are shown in Figure II-1. Water use is about 77 gpm or 110,000 gpd.

The bath chemicals employed for both scouring and desizing are soda ash and mercaptan scour. The mill controls the chemical dosages for washer #1 to maintain about 4 to 5 grams per liter of soda ash and 0.75 to 1 gram per liter of mercaptan scour. The dosages of chemicals on washer #2 are not carefully controlled. Mill data from a typical production week show a use of 6900 lbs of soda ash per week and 2300 lb/wk of mercaptan scour. This is a 3:1 ratio, as compared to about 4:1 on washer #1. This indicates the use of a different soda ash/mercaptan scour ratio in washer #2.

Wastewater Characterization

Wastewater samples from scouring and desizing were collected and analyzed. The results are shown in Table II-1. Table II-2 summarizes the amounts of the various chemicals remaining in the wastewater. The basis for these estimates is as follows. The wastewater

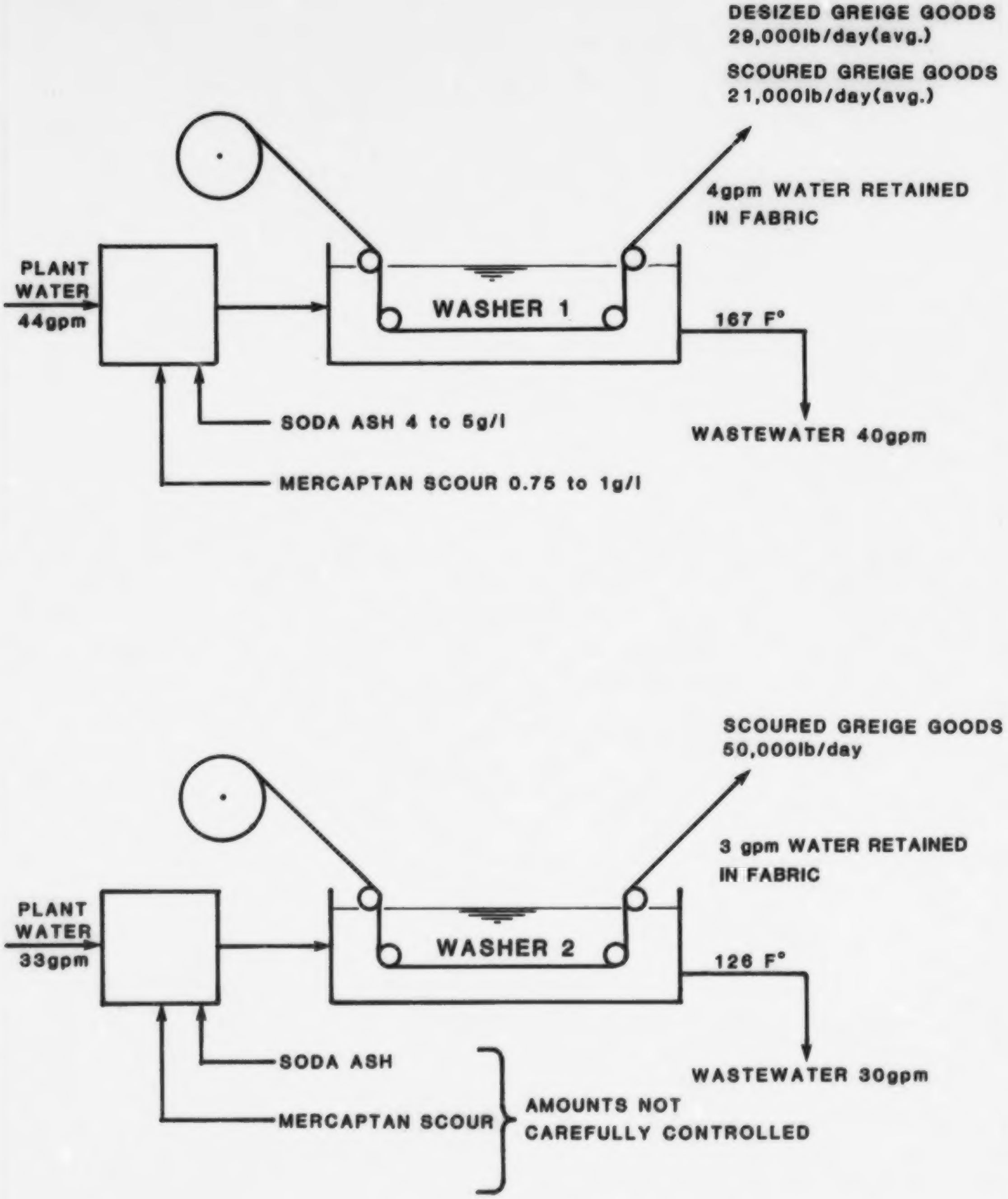

DESIZED GREIGE GOODS
29,000lb/day(avg.)
SCOURED GREIGE GOODS
21,000lb/day(avg.)
4gpm WATER RETAINED IN FABRIC
PLANT WATER 44gpm
WASHER 1
167 F°
SODA ASH 4 to 5g/l
WASTEWATER 40gpm
MERCAPTAN SCOUR 0.75 to 1g/l
SCOURED GREIGE GOODS
50,000lb/day
3 gpm WATER RETAINED IN FABRIC
PLANT WATER 33gpm
WASHER 2
126 F°
SODA ASH
WASTEWATER 30gpm
MERCAPTAN SCOUR
AMOUNTS NOT CAREFULLY CONTROLLED

FIGURE II-1
DESIZE/SCOUR WASHERS

TABLE II-1
WASTEWATER CHARACTERIZATION
DESIZING AND SCOURING

	Concentration, mg/l		
	Desizing	Scouring	
Alkalinity	2,200	300	14
BOD	660	100	72
COD	2,600	1,200	1,300
TOC (% by weight)	0.26	--	--
TDS	5,100	240	77
TSS	95	3	8
Chloride	40	18	--
Phenolics	0.004	0.057	0.005
Oil & Grease	93	24	220
Turbidity (NTU)	280	150	240
Color (ADMI)	630	530	1470
Calcium	2.6	2.9	2.5
Magnesium	2.1	1.4	1.5
Sodium	1000	160	23
Chromium	< 0.2	< 0.2	< 0.2
Copper	< 0.2	< 0.2	< 0.2
Iron	0.73	0.58	0.28
Lead	< 0.2	< 0.2	< 0.2
Manganese	< 0.1	< 0.1	< 0.1
Nickel	< 0.1	< 0.1	< 0.1
Zinc	0.15	0.12	< 0.1
pH (S.U.)	10.1	8.2	7.8
Temperature (°F)	167	126	106

Source: Wastewater samples from March 15 to 17, 1982.

TABLE II-2
ESTIMATED CHEMICALS IN DESIZE AND SCOUR WASTEWATER

	Chemical Quantity, lb/day		
	Washer 1		Washer 2
Chemical	Desize	Scour	Scour
Soda Ash	663	442	63
Mercaptan Scour	166	110	16
Acrylic Size	2,516	-	-
Spinning Oils	232	168	400

Source: Mill data on chemical use, discussions with mill personnel, and wastewater sampling data.

data for sodium (1,000 mg/l) and alkalinity (2,200 mg/l) indicate the amount of soda ash remaining in the desize wastewater. The values are used to estimate the amount of soda ash consumed in the operation, and the 4:1 soda ash/mercaptan scour ratio is used to estimate the amount of mercaptan scour remaining. The mill estimates that oils are present at about 1 percent of the weight of fabric, which would result in a 0.12 percent concentration of oils in the wastewater assuming they are completely removed in the washing. The scour wastewater data show that soda ash is applied at a lower and variable concentration based on alkalinity values of 300 mg/l and 14 mg/l and sodium values of 160 mg/l and 23 mg/l.

As stated earlier, about 29 percent of the total wet production is desized. The mill is capable of scheduling long runs of sized goods through washer #1 in order to segregate the desize from the scour wastewater. Thus, desizing occurs from 2½ to 3 days per week, only on washer #1. The washer typically generates 40 gpm wastewater at 167°F, while washer #2 generates 30 gpm at 126° F. The continuous discharge from the washers drops into separate troughs below each washer, which lead to a pipe in which the washer discharges combine and flow into the main discharge pit in the mill before entering the heat exchanger.

The wastewater data in Tables II-1 and I-3 indicate that the desize operation contributes a substantial organic load to the mill's final effluent. As noted in Section I, this stream contributes 4 percent of the total flow, but 12 percent of the total BOD. This is attributable to the acrylic size, oils, and waxes that are removed in the operation. The scour wastewater data indicate that the organic load from this operation is also substantial, particularly due to the impurities being removed.

DESCRIPTION OF APPLICABLE RECYCLE/REUSE METHODS

The alternatives for recycle consist of 1) recycle system for the desize wastewater only, 2) recycle system for both scour and desize wastewater.

Alternative 1 - Ultrafiltration of Desize Wastewater

The revised process under Alternative 1, including size recovery system and water recycle, is illustrated in Figure II-2. The objectives of the process are to: 1) remove excessive impurities and enable recovery or reuse of valuable chemicals, particularly the size; 2) reuse energy and water; 3) reduce pollutant loadings and COD surcharge.

The essential means of accomplishing the objectives is through ultrafiltration, a low pressure membrane separation technique to concentrate the valuable size and allow other bath chemicals (soda ash, mercaptan scour, defoamer) to pass through in the hot permeate and be recycled to the desize washer.

Desize wastewater is passed through a vibrating screen filter for gross solids removal before entering a continuous multi-stage feed and bleed ultrafiltration system (illustrated in Figure II-3). The hot permeate from the system is returned to the desize bath, and the concentrated size is centrifuged (if necessary) for oil removal before reuse in the slasher. The removed oils may be stored for combustion in the boilers.

The technical and economic feasibility of this alternative is covered below under "Technical Feasibility" and "Economic Feasibility."

Alternative 2 - Alternative 1 Plus Ultrafiltration of Scour Wastewater

Alternative 2 includes an ultrafiltration system for the scouring wastewater, in addition to the desize wastewater, with similar objectives except to separate oils from the wastewater instead of size. Therefore, this part of the system will be known as the oil separation system. The recovered wastewater, containing the auxiliary chemicals, is recycled to the scour washer.

As discussed earlier, scouring is conducted on both washer #1 and washer #2 for unsized goods, which represent 71 percent of production. Washer #1 discharges 40 gpm at about 167°F for an average of two days per week, 24 hrs/day, for unsized goods, and washer #2 discharges 30 gpm at about 126°F for five days per week, 24 hours/day, for unsized goods.

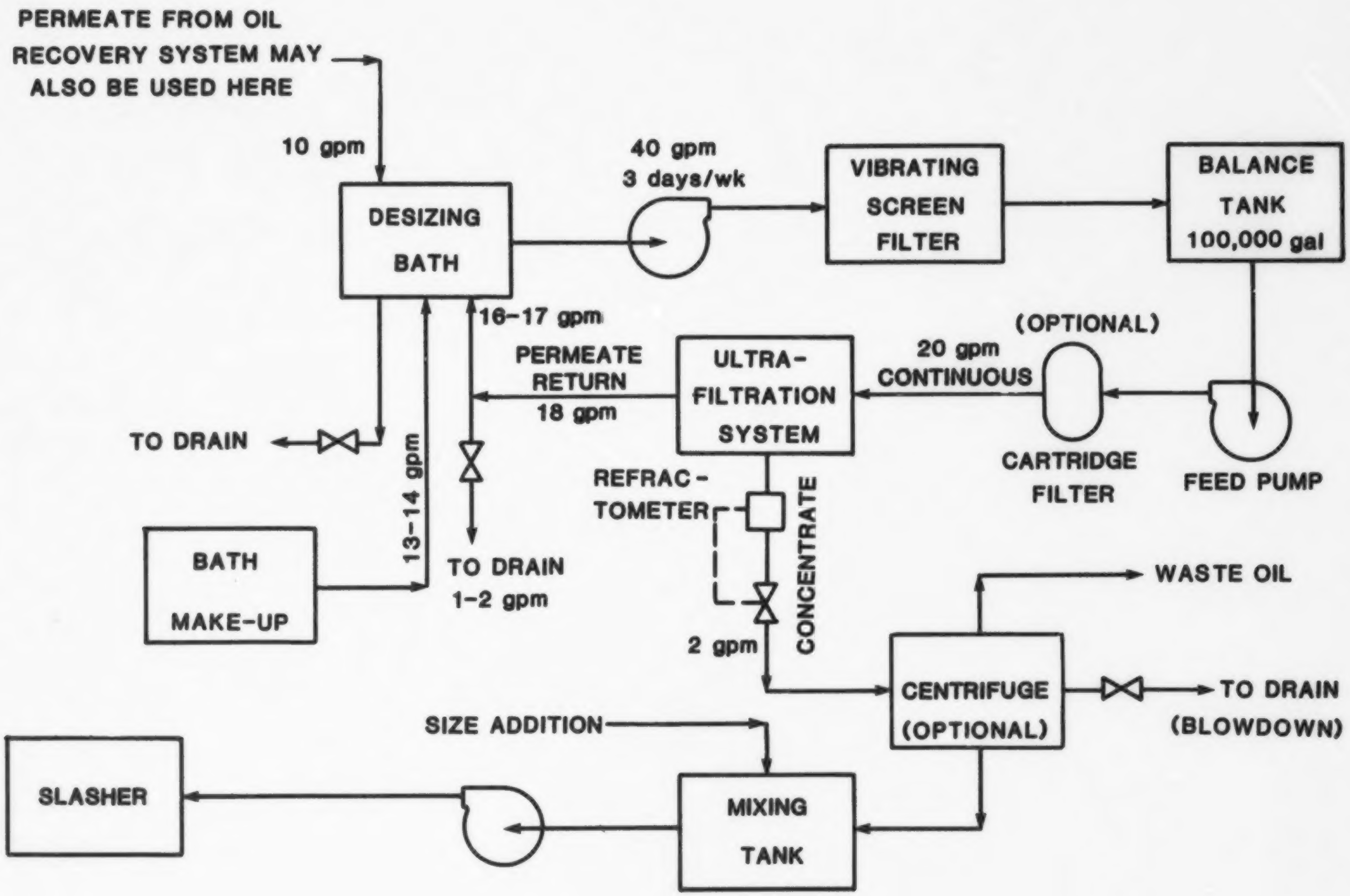

PERMEATE FROM OIL RECOVERY SYSTEM MAY ALSO BE USED HERE
10 gpm
DESIZING BATH
40 gpm
3 days/wk
VIBRATING SCREEN FILTER
BALANCE TANK 100,000 gal
16-17 gpm
PERMEATE RETURN
18 gpm
ULTRA-FILTRATION SYSTEM
(OPTIONAL)
20 gpm
CONTINUOUS
CARTRIDGE FILTER
FEED PUMP
TO DRAIN
13-14 gpm
TO DRAIN
1-2 gpm
BATH MAKE-UP
REFRAC-TOMETER
CONCENTRATE
2 gpm
WASTE OIL
CENTRIFUGE (OPTIONAL)
TO DRAIN (BLOWDOWN)
SIZE ADDITION
SLASHER
MIXING TANK

FIGURE II-2 SIZE RECOVERY SYSTEM

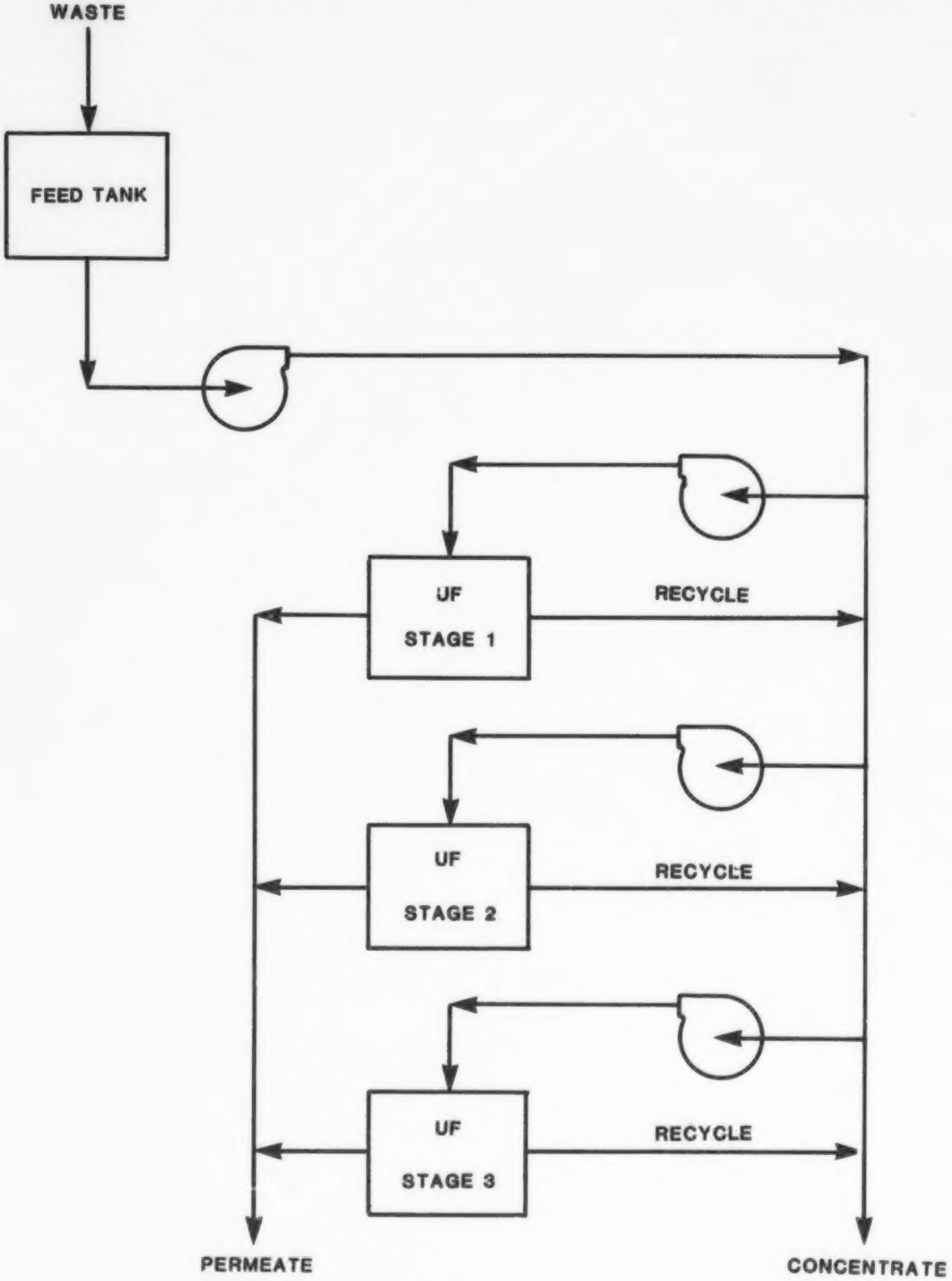

WASTE
FEED TANK
UF
STAGE 1
RECYCLE
UF
STAGE 2
RECYCLE
UF
STAGE 3
RECYCLE
PERMEATE
CONCENTRATE

FIGURE II-3. CONTINUOUS MULTI-STAGE FEED & BLEED OPERATION

The ultrafiltration system should be capable of handling the flow as described above, a total of 330,000 gallons/wk. The peak flow will be about 70 gpm, and the continuous average flow is about 45.8 gpm.

The oil separation system is illustrated in Figure II-4. Scour wastewater passes through both a vibrating screen and cartridge filter before entering the continuous multi-stage feed and bleed ultrafiltration system. The permeate from the system is returned to the scour or desize bath, and the concentrate is stored for subsequent combustion in the boilers. The expected oil content in the concentrate is 20,000 to 40,000 ppm.

TECHNICAL FEASIBILITY

Previous History

Several full scale ultrafiltration size recovery systems have been installed for recovery of PVA size and other synthetic sizes (WD, for example). Pilot testing for recovery of acrylic sizes has also been successful (Reference 1).

The two primary membrane configurations that have been successful are the tubular configuration sold by Gaston County Filtration Systems, Stanley, NC, and the spiral-wound configuration of Abcor, Inc., Wilmington, MA. A hollow fiber type has shown some promise at pilot and bench scale, but no full scale units have been installed. The spiral wound configuration exhibits a greater membrane area per unit volume than the tubular type, resulting in a smaller space requirement, but it is more susceptible to plugging and fouling. Thus, it generally requires both a vibrating screen filter and a cartridge filter for prefiltration. Thus far, the useful life of the spiral-wound membranes has not exceeded 2 years, while the tubular system membranes have gone 7 years without fouling.

The tubular system requires a 100 to 150 mesh vibrating screen for prefiltration, plus somewhat greater surface area, floor space, and horsepower for higher flux rates. The membranes are installed in a 6 mm ID carbon tube, which is unlikely to plug and has not plugged in the full scale installations. The tubular membranes withstand a greater pH and temperature range than the spiral-wound and hollow fiber types.

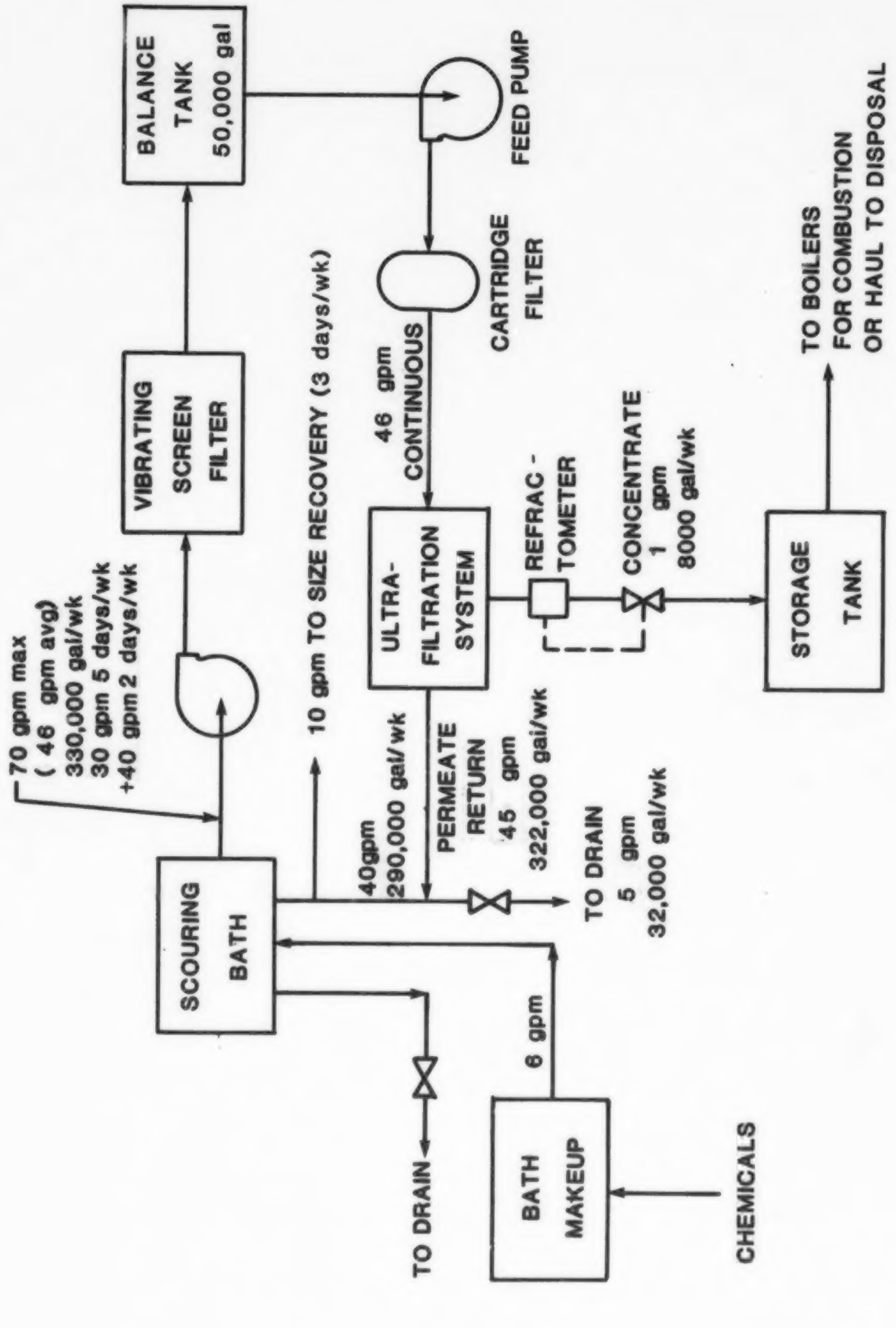

SCOURING BATH
70 gpm max
(46 gpm avg)
330,000 gal/wk
30 gpm 5 days/wk
+40 gpm 2 days/wk
VIBRATING SCREEN FILTER
BALANCE TANK 50,000 gal
FEED PUMP
CARTRIDGE FILTER
46 gpm CONTINUOUS
10 gpm TO SIZE RECOVERY (3 days/wk)
ULTRA-FILTRATION SYSTEM
REFRAC - TOMETER
CONCENTRATE 1 gpm 8000 gal/wk
STORAGE TANK
TO BOILERS FOR COMBUSTION OR HAUL TO DISPOSAL
40gpm
290,000 gal/wk
PERMEATE RETURN
45 gpm
322,000 gal/wk
TO DRAIN
5 gpm
32,000 gal/wk
6 gpm
TO DRAIN
BATH MAKEUP
CHEMICALS

FIGURE II-4 OIL RECOVERY SYSTEM

The oil separation system is virtually the same as the size recovery system but likely will include a cartridge filter before the ultrafiltration system. The reason for this is that pilot plant work for oil recovery has been successful with the Abcor spiral wound membrane configuration, as opposed to the tubular configuration of Gaston County Filtration Systems successful in size recovery systems.

And although the tubular unit was successful during the bench scale tests (see Appendix A), the spiral-wound configuration is the basis for the preliminary design of the oil separation system.

Volume 1 contains a detailed review of applications information for ultrafiltration.

Bench Scale Results

A bench scale test of ultrafiltration (UF) was conducted by Gaston County Filtration Systems to further evaluate the feasibility of UF at this mill for size and oil recovery. A brief description of their method and equipment is found in Appendix A.

Although phase separation was demonstrated in the desize and scour wastewater, the analytical results, shown in Table II-3, indicate that a substantial portion of the size passes through the membrane. The indicators are the COD, which is reduced from 2600 mg/l in the wastewater to 1,100 mg/l in the permeate, and total carbon, reduced from 0.26 percent by weight in the wastewater to 0.16 percent in the permeate. In the scour wastewater, the COD was reduced from 1200 mg/l to 40 mg/l in the permeate, further substantiating the opinion that size is passing through the membrane and oils are being separated.

Mill personnel and other consultants indicate that the acrylic size may be chemically altered in the hot alkaline conditions of the desizing bath, probably causing the molecular weight to drop substantially through breaking of carbon-carbon bonds with the interaction of oxygen.

It is difficult to assess the extent of size degradation due to alkaline conditions based on the data available presently, because the time lag between sample collection, bench testing, and sample analysis was several days, and this time period can also contribute to size degradation in the wastewater.

TABLE II-3
ANALYTICAL RESULTS
BENCH SCALE TEST OF ULTRAFILTRATION

	Concentration (mg/l)				
	Desize Wastewater	UF Permeate Desize	Scour Wastewater		UF Permeate Scour
Alkalinity (as $CaCO_3$)	2,200	1,500	300	14	42
BOD	660	150	100	72	2
COD	2,600	1,100	1,200	1,300	40
TOC (% by weight)	0.26	0.16	--	--	--
TDS	5,100	2,700	240	77	150
Chloride	40	38	18	--	11
Phenolics	0.004	0.004	0.057	0.005	0.040
Oil & Grease	93	19	24	220	8
Turbidity (NTU)	280	0.22	150	240	0.25
Color (ADMI Units)	630	16	530	1,470	8
Calcium	2.6	0.78	2.9	2.5	0.92
Magnesium	2.1	0.42	1.4	1.5	0.78
Sodium	1,000	820	160	23	36
Chromium	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Copper	< 0.2	--	< 0.2	< 0.2	< 0.2
Iron	0.73	0.35	0.58	0.28	0.39
Lead	< 0.2	--	< 0.2	< 0.2	< 0.2
Manganese	< 0.1	--	< 0.1	< 0.1	< 0.1
Nickel	< 0.1	--	< 0.1	< 0.1	< 0.1
Zinc	0.15	--	0.12	< 0.1	< 0.1
pH (S.U.)	10.1	--	8.2	7.8	9.7

Further Technical Investigations

In order to evaluate more thoroughly the technical feasibility of size and oil recovery at this mill, the following investigations are recommended:

- Collect further data on size removal in the desizing operation to evaluate the efficiency of the operation, and to evaluate the possible alteration or degradation of the size in the desizing operation due to alkaline and hot temperature conditions.
- Evaluate the usefulness of the recovered size by testing at the slasher and observing effects on weaving efficiency, desizing, and dyeing. Of special consideration is the effect of the suspected chemical alteration of the size due to hot alkaline conditions.
- Investigate the effect on size removal, size degradation, and water and energy savings by varying the desizing procedure to include a hot water wash stage followed by a second stage alkaline wash.
- Conduct further testing of various membranes to identify the optimum membrane and develop flux data.
- Evaluate the usefulness of the recovered oils and their value as a fuel or for reuse in fiber manufacturing.

TECHNICAL DESIGN CRITERIA

Alternative 1 - Ultrafiltration of Desize Wastewater

In order to segregate the desize wastewater, the mill can schedule long runs of sized goods through the washer for about 3 days per week.

The ultrafiltration system must take this into consideration. For example, though the average daily flow over a week would be 29,000 gpd (based on 29 percent of the total washer flow of 100,000 gpd, the peak desize wastewater flow at 40 gpm would be 57,600 gpd. Therefore, the storage capacity and ultrafiltration system capacity must be capable of handling this. The total flow of 40 gpm for 70 hours would be 168,000 gallons.

In order to establish a preliminary design for the ultrafiltration unit, assumptions must be made on the expected flux value through the unit - this is to be more definitely established during pilot plant operation. Values in the literature* range from about 30 to 100 gallons/ft^2/day (GFD) depending on the temperature, inlet feed pressure, and membrane type and configuration.

Typically, at least an 8 hour holding capacity is recommended to allow independent operation of the washer and ultrafiltration system. Based on Gaston County Filtration Systems (GCFS) previous experience, they expect an overall flux rate of 30 GFD. Each GCFS loop contains 480 ft^2 of membrane area, thus providing a flow capacity of 10 gpm per loop. GCFS expects that the mill can cut water use slightly from 8 lbs water per lb fabric to 6 or 7 lbs water per lb of fabric; with this provision, and with provision of a 100,000 gallon storage tank, the UF system can be designed for 2 loops for optimum capital cost. Each loop will handle 10 gpm continuously.

Table II-4 summarizes the design criteria for this recycle system.

Alternative 2 - Alternative 1 Plus Ultrafiltration of Scour Wastewater

Preliminary design of the ultrafiltration system is based on pilot plant work conducted by Abcor. Abcor carries a factory assembled system, No. 545, which is expected to recover 8,000 gallons of concentrate from the total flow of 330,000 gallons per week. The design criteria for this recycle system are summarized in Table II-5.

ECONOMIC FEASIBILITY

Cost savings from recycling desize and scour wastewater result from water use savings, sewer surcharge savings, auxiliary chemical savings, size recovery, and energy savings. Operating costs result from operation of the ultrafiltration system. Operating and cost savings were developed for the recycle of desize wastewater and for the recycle of scour wastewater. The basis for the costs and savings are as follows:

---

* Literature references in Volume 1.

TABLE II-4
DESIGN CRITERIA - ULTRAFILTRATION FOR SIZE RECOVERY

Parameter	Units	Value
Wastewater		
Average (Design) Flow	gpm	20
Peak Flow	gpm	40
Temperature	°F	167
Size Content	Percent	1
Equalization		
Volume	Gallons	100,000
Ultrafiltration		
Membrane Type	--	Tubular Zirconium Oxide
System Type		Multi-Stage, Continuous Feed and Bleed
Number of Loops	--	2
Flow per Loop	gpm	10
Membrane Area per Loop	ft^2	480
Flux Rate	$Gal/Ft^2/Day$	30
Recovery	Percent	90
Operating Pressure	psig	150

TABLE II-5
DESIGN CRITERIA - ULTRAFILTRATION FOR OIL RECOVERY

Parameter	Units	Value
Wastewater		
Average (Design) Flow	gpm	46
Peak Flow	gpm	70
Temperature	°F	167
Oil Content	Percent	0.1
Equalization		
Volume	Gallons	30,000
Ultrafiltration		
Membrane Type	--	Spiral Wound
System Type	--	Multi-Stage, Continuous Feed and Bleed
Operating Pressure	psig	50
Flux Rate	Gal/Ft^2/Day	**

** Flux rate must be determined by pilot testing.

- Water and wastewater (volume) savings of \$0.83 per 1,000 gallons.
- Wastewater surcharge savings of 3.3 cents per pound of COD for COD > 600 mg/l.
- Chemical savings of: 11.3 cents/lb soda ash
  78 cents/lb mercaptan scour
  40 cents/lb acrylic size
- Energy savings of \$4.30 per million BTU.
- Ultrafiltration system capital and operating costs from information contained in Volume 1.

Other assumptions include the following:

- Desizing and scouring are conducted 250 days/yr.
- Ultrafiltration system is designed to recover 80% of the acrylic size.
- Eighty percent of the auxiliary chemicals in the wastewater are recycled to the washer in the permeate.
- Energy savings are based on the current situation of raising preheated plant water from 110°F to 167°F for washer #1 and from 110°F to 126°F for washer #2.

Table II-6 presents an analysis of these operating savings and costs.

Estimated capital costs (June 1982) and the resulting payback periods for the two alternatives are as follows.

	Capital Cost	Annual Savings	Payback (years)
Recycle-Desize	\$550,000	\$ 217,000	2.5
Recycle-Desize & Scour	\$1,072,000	\$ 119,000	9

Note that there is no incremental payback for adding recycle to the scour wastewater, since the annual savings are lower for recycle of both desize and scour wastewater.

From Table II-6 it is apparent that the recovery of acrylic size is the item that makes recycle economically attractive, accounting for over 80 percent of the annual savings.

TABLE II-6

OPERATING SAVINGS FOR ULTRAFILTRATION
TREATMENT AND RECYCLE OF DESIZE/SCOUR WASTEWATER

			Scour		
		Desize	Washer 1	Washer 2	Total
Water Use/Wastewater	(gpd)	25,600	22,400	40,000	62,400
	($/yr)	5,300	4,600	8,300	12,900
COD Surcharge	(lb/day)	500	200	400	600
	($/yr)	3,100	800	1,500	2,300
Auxiliary Chemicals	($/yr)	41,000	27,200	3,900	31,000
Acrylic Size	(lb/day)	2,000	0	0	0
	($/yr)	201,300	0	0	0
Energy Savings	(10^6 BTU/day)	6.4	10.6	5.3	15.9
	($/yr)	6,200	10,300	5,200	15,500
Recycle Operating Costs	($/yr)	($40,000)	-	-	($160,000)
Net Annual Savings	($/yr)	$217,000			$119,000 for system with desize & scour

Current (1982) prices for various types of sizing agents are as follows:

PVA	$ 1.20
CMC	$ 1.00
Acrylic	$ 0.40

Therefore, the above noted payback period for acrylic size is consistent with the reported payback periods of 9 to 18 months with more expensive PVA and CMC sizes.

ENVIRONMENTAL EFFECTS

The environmental effects of the ultrafiltration/reuse systems can be estimated from Table I-3. The most significant effects of reuse are the decreased organic load (BOD, COD) and suspended solids load.

It is uncertain what the effect of the ultrafiltration membrane will be on the final wastewater quality and whether any adverse effects will occur, such as dumps of concentrated solutions in cleanup that may contain priority pollutants such as metals. This is worthy of further technical investigation during pilot testing.

CONCLUSIONS

- The technical feasibility of size recovery needs additional investigation at this mill because of suspected chemical degradation of the size in desizing.
- Estimates of capital costs need to be better defined through pilot plant testing to establish flux data.
- The economic feasibility is reasonably promising because of the great savings in size costs. The situation would be much better at other mills that use more expensive sizes, such as PVA and CMC.
- The effects of ultrafiltration on final wastewater quality need further investigation.
- Oil separation through ultrafiltration is not economically attractive unless a great value can be found for the oils.

SECTION III
DYEBATH RECONSTITUTION

DESCRIPTION OF MANUFACTURING PROCESS

General

The mill performs a large variety of dyeing procedures in order to fill all orders. All dyeing is performed on jet dyeing machines of various styles and capacities to allow for substantial flexibility. The various dye formulations break down to the following major types:

- 100 percent polyester - disperse dyes only. This represents 60 percent to 70 percent of production currently, but the market varies.
- Modified polyester - cationic dyes only.
- Polyester/modified polyester blend - disperse/cationic dyes.
- Polyester/wool blend - disperse/acid dyes.
- Polyester/wool blend - acid dye only (polyester not dyed).
- Polyester/cellulose (rayon or cotton) - disperse/direct dyes.

Mill personnel feel that blends will occupy a greater portion of their dyeing in the future though admittedly the market is somewhat unpredictable. However, most of the dye personnel feel that 100 percent disperse dyeable polyester will always occupy a large part of their production because this is where their experience and expertise lie.

Therefore, examination of the potential for dyebath reconstitution will focus on the disperse dyeing portion of production.

Production and Machinery

Typical production at the mill is estimated to be 500,000 lb/wk, though mill capacity is approximately 750,000 lbs/week. Currently, 60 to 70 percent of production is 100 percent polyester (disperse dyeable), 15 to 20 percent is polyester/wool, 5 to 10 percent is polyester/cellulose, and the remaining portion is filled by polyester blends and modified polyester.

The current dyeing machinery is summarized in Table III-1, along with the maximum number of cycles per day and the expected water use per cycle.

It should be pointed out that dye formulations are controlled by a central computer system, so that the dyeing personnel know the type of dyeing occurring in a particular machine at all times, as well as the status of the dyeing process with time. This system enables personnel to monitor and control the dyeing quality with relative ease, especially considering the complex nature of each formulation and the large variety of procedures.

EVALUATION OF POTENTIAL FOR DYEBATH RECONSTITUTION

Discussions with mill personnel reveal that they are hesitant to explore dyebath reconstitution at the mill, though they can foresee the benefits of it if their dyeing schedule allowed it. The scheduling of shades and dye types varies tremendously from day to day, and the mill must maintain flexibility.

Technical Feasibility

Production information and the physical layout dictate that the evaluation should focus on the 100 percent disperse dyeable polyester portion of production that is conducted in the six-port and three-port dyeing machines. The majority of the dyeing wastewater (88 percent) is generated in these machines, and the major portion of production in performed in these machines. Since there are seven (7) six-port machines and five (5) three-port machines, overall flexibility should not be significantly affected if several of these machines were allocated primarily for 100 percent disperse dyeing.

TABLE III-1

DYEING MACHINERY WATER USE

Type of Machine[1]	No. Machines[1]	Water Use Per Cycle Gallons[2]	Maximum[3] Daily Water Use Gallons
Six-Port	7	7,500	262,500
Three-Port	5	9,000	225,000
One-Port	2	1,200	12,000
Four-Port	1	5,000	25,000
Two-Port	1	2,500	12,500
Hisaki FL-1	2	1,000	10,000
Hisaki FL-2	1	2,000	10,000
Total Maximum Water Use			557,000
Typical Daily Water Use			500,000
Typical Wastewater Discharge			450,000

Notes:

(1) From Mill Layout

(2) Mill Personnel Estimates

(3) Calculated Value = No. Machines x 5 cycles/day x Water Use Per Cycle

Studies at Georgia Tech (Reference 5) demonstrate the technical feasibility of the reconstitution of disperse dyebaths, as well as its applicability to jet dyeing machines. Volume 1 summarizes technical information on the applicability of reconstitution in dye houses.

Mill personnel provided detailed information on a predominant dyebath with 100% disperse dyes. For a 6-port jet dye machine, the following procedure is followed:

Fill with 1,500 gallons water at about 158°F
Add 1,681 lbs of fabric (3,212 yards)
Add dyestuffs and auxiliary chemicals, as shown below:
18 lbs ester based leveller
36 lbs lubricant/soil release finish
30 lbs defoamer, 7.5 lbs acetic acid (56 percent solution) pH control
8,525 grams (18.8 lbs) dyestuff A
8,855 grams (19.5 lbs) dyestuff B
7,928 grams (17.5 lbs) dyestuff C

The temperature is slowly raised to 250°F and maintained for 30 to 60 minutes, with monitoring to determine the end point of the process. The temperature is allowed to drop slowly to 158°F by means of an overflow rinse of about 6,000 gallons.

The dyeing process as described above is not particularly suited for direct reconstitution and reuse because of the dilution that occurs from the overflow rinse. Mill personnel have stated that a change in cooling and rinse procedures is probably technically feasible to allow for dyebath reuse. Mill personnel may be willing to test a procedure in which the concentrated dyebath is sent to storage and followed by a rinse with preheated clean water. They feel this rinse procedure will likely not adversely affect the quality of the dyeing. The one disadvantage of this revised procedure is that it would negate some of the potential energy savings from reconstitution. Another possibility is to let the dyebath cool naturally or by heat exchangers to a temperature below the dye strike temperature.

Two basic methods of storage and reuse have been identified through the literature and field investigations. The first is that illustrated in Figure III-1 in which the spent dyebath is pumped to a holding tank, analyzed spectrophotometrically, stored until needed, and then reconstituted for dyeing the next batch. The second procedure is to store the dyebath in the original machine and to transfer the fabric to another machine for rinsing.

The first method described above is seen to be most applicable to this mill because of difficulties in moving fabric between dye machines and the required slow cooling.

As noted earlier, disperse dyeing of polyester has been demonstrated to be amenable to dyebath reconstitution. We feel, however, that testing is needed to verify that the quality of dyeing is not adversely affected by the change in rinse procedures. Testing would also indicate the permissible sequences of dye shades for scheduling on the machines.

Economic Feasibility

Cost savings are realized in the areas of water use, wastewater discharge, auxiliary chemical use, and energy. Additional operating costs will be incurred for dyebath pumping and rinse water preheating. Operating costs and savings were developed for three cases:

Case 1. Reconstitution on one 6-port and one 3-port machine.
Case 2. Reconstitution on two 6-port and one 3-port machine.
Case 3. Reconstitution on two 6-port and two 3-port machine.

The basis for the costs and savings are as follows:

- Water and wastewater (volume) savings of $0.83 per 1,000 gallons.
- Wastewater surcharge savings of 3.3 cents per pound of COD, for COD $>$ 600 mg/l.
- Chemical savings of $0.022 per pound of fabric (see Table III-2).

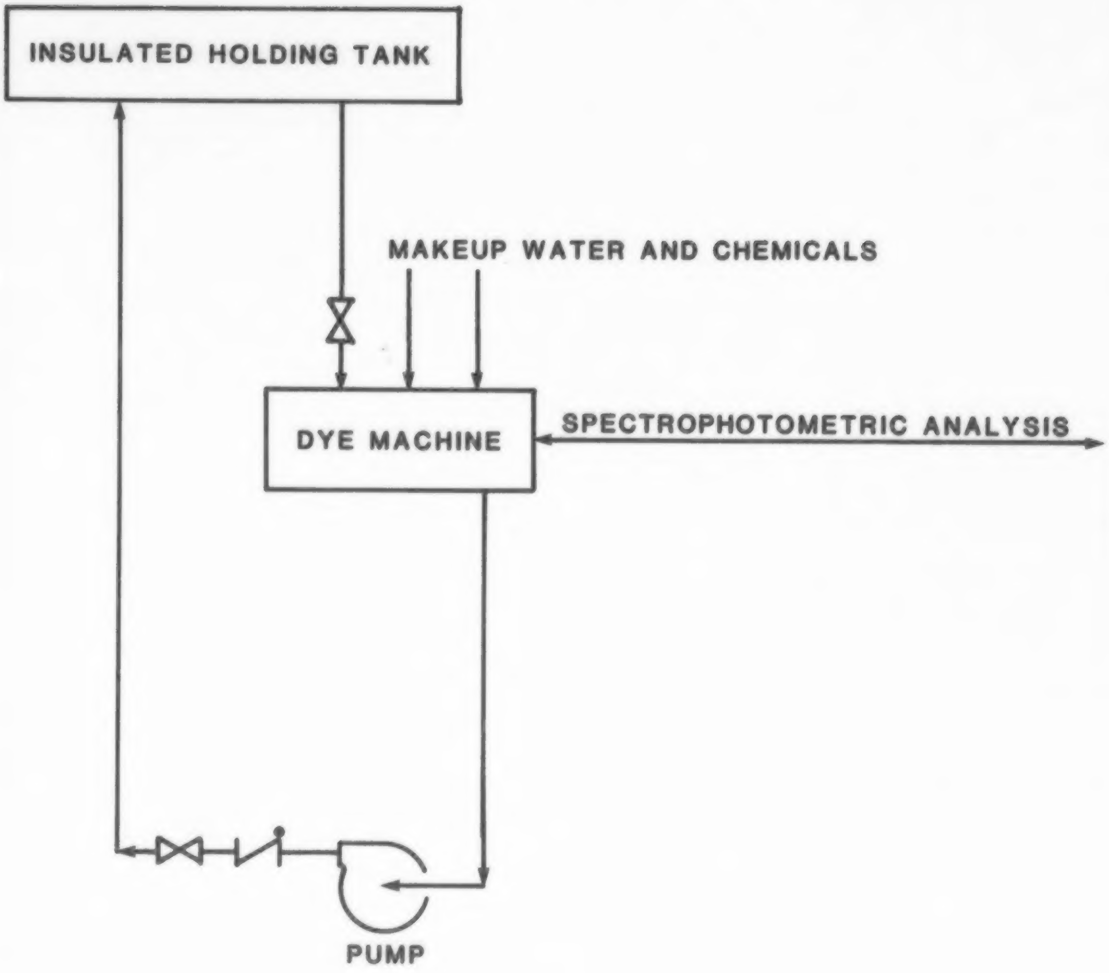

INSULATED HOLDING TANK
MAKEUP WATER AND CHEMICALS
DYE MACHINE
SPECTROPHOTOMETRIC ANALYSIS
PUMP

FIGURE III-1
DYEBATH RECONSTITUTION SCHEMATIC

TABLE III-2
RECOVERABLE CHEMICAL VALUE IN PREDOMINANT DYEBATH

Chemical Type	Amount lbs	Price ¢/lb(1)	% Exhaustion(2)	Recoverable Value(3)
Leveller	18	72	20	$ 10.37
Lubricant	36	63	80	$ 4.54
Defoamer	30	87	20	$ 20.90
Acetic Acid	7.5	14.5	20	$ 0.87
Dyestuffs			95	--
Total				$ 36.68

Recoverable chemical value per lb fabric = $36.68 ÷ 1,681 lb
= $ 0.022/lb fabric

Notes:

(1) From Mill Records

(2) Mill Estimate

(3) Calculated Value = lbs x ¢/lb x (1 - Percent Exhaustion)

- Energy savings and cost of $4.30 per million BTU.
- Capital and operating costs are explained in Volume 1.

Other assumptions include the following:

- Four dyebath drops are reconstituted per day for each machine (5 dyeing cycles).
- 6-port machine uses 1,500 gallons dyebath to dye 1,500 pounds fabric.
- 3-port machine uses 1,800 gallons dyebath to dye 1,800 pounds fabric.
- Reconstituted dyebath temperature is 158°F; plant water temperature is 110°F; energy savings based on difference of 48°F.
- Average COD of spent dyebath is 5,100 mg/l.
- Dyeing is performed 250 days per year.

Table III-3 presents an analysis of these operating costs and savings.

Estimated capital costs (June 1982) for the three cases presented above are:

Case 1	$35,000
Case 2	$57,000
Case 3	$65,000

These costs include:

Insulated elevated storage tanks for dyebath storage.
Related pumps and piping.
Electrical service for pumps.
Access platform at tanks.
Spectrophotometer for dyebath analysis.
Engineering design costs.

The resulting payback period for the three cases are as follows:

TABLE III-3
OPERATING SAVINGS
FOR DYEBATH RECONSTITUTION

		Case 1	Case 2	Case 3
Water/Wastewater	(gpd)	13,200	19,200	26.400
	($/yr)	2,700	4,000	5,500
COD Surcharge	(lb/day)	560	820	1,120
	($/yr)	4,100	5,900	8,100
Auxiliary Chemicals	($/yr)	76,000	110,000	152,000
Energy Savings*	(10^6 BTU/day)	5.3	7.7	10.6
	($/yr)	5,100	7,500	10,300
Energy Cost*	(10^6 BTU/day)	11.0	16.0	22.0
	($/yr)	(11,800)	(17,200)	(23,600)
Operating Supplies	($/yr)	(4,000)	(4,000)	(4,000)
Net Annual Savings	($/yr)	72,100	106,200	148,300

* Energy savings due to hot, recycled dyebath. Energy cost due to need for heated rinse water.

	Capital Cost	Annual Savings	Payback (months)
Case 1	$35,000	$ 72,100	6
Case 2	$57,000	$106,200	6
Case 3	$65,000	$148,300	5

As indicated on Table III-3, the value of auxiliary chemicals in the reconstituted dyebath is the major area of cost savings. It would appear that to ensure a payback period of one year of less under the above defined cost basis, a minimum recoverable chemical value of about $0.013 per pound of fabric processed is needed.

ENVIRONMENTAL EFFECTS

As indicated on Table III-4, the institution of dyebath reconstitution on as few as two to four of the mill's 19 dye machines will result in significantly lower discharges of pollutants from the mill. The values in the table do not take into account the possible build-up in some pollutant concentrations in the dyebath caused by recycle, which would then be released in the final dyebath drop.

CONCLUSIONS

- Dyebath reconstitution has been shown to be feasible in similar applications as this (disperse dyeing of polyester in jet dye machines).
- Only two to four of the dye machines should initially be dedicated for reconstitution in order to maintain dyeing flexibility.
- Significant environmental benefits can result from the institution of dyebath reconstitution.
- The economics of reconstitution appear favorable: payback period of 5 to 6 months.
- Testing should be performed to verify the feasibility of a modified rinsing/cooling system, to verify that product quality is unaffected by dyebath reuse, and to verify the assumed auxiliary chemical savings.

TABLE III-4
ENVIRONMENTAL BENEFITS OF DYEBATH RECONSTITUTION

		Case 1	Case 2	Case 3
Flow Reduction	(gpd)	13,200	19,200	26,400
	(% Total)	2	3	4
BOD Reduction	(lb/day)	100	140	200
	(% Total)	8	11	15
COD Reduction	(lb/day)	560	820	1,120
	(% Total)	8	12	16
TSS Reduction	(lb/day)	8	12	17
	(% Total)	1	2	3
Phenolics Reduction	(lb/day)	0.1	0.14	0.2
	(% Total)	11	15	21

SECTION IV

CHEMICAL OXIDATION OF DYE WASTEWATER

DESCRIPTION OF MANUFACTURING PROCESS

Dyeing at this mill is described in detail in the discussion of dyebath reconstitution. For the purpose of discussion of chemical oxidation, consideration is given to the predominant dyeing type, namely, disperse dyeing of 100 percent polyester fabric, which comprises 60 to 70 percent of all dyeing at the mill. It is estimated that 60 percent of the wastewater generated in dyeing (450,000 gpd) results from the disperse dyeing, and this discharge of 270,000 gpd is the basis for examining design criteria and the economics of chemical oxdiation at this mill. The composite discharge temperature is about 108°F, but individual baths may be discharged at about 158°F.

As shown earlier, the dye wastewater contributes the greatest pollutant load of all the processes to the final effluent, particularly COD. See Tables I-3 and IV-1 for loads from the various processes and concentrations from dyeing.

DESCRIPTION OF APPLICABLE RECYCLE/REUSE METHODS

The revised process schematic incorporating recycle is illustrated in Figure IV-1. The 270,000 gpd of disperse dyeing wastewater are segregated so that auxiliary chemicals can be reused consistently, and fairly consistent treatment requirements can be experienced. Some piping and process control modifications are needed in order to be able to segregate the disperse dye wastewater.

The wastewater enters a series of treatment tanks in which it is decolored by chlorine oxidation, with pH adjustment by liquid caustic or soda ash, and dechlorination by sulfur dioxide, sodium bisulfite, or sodium thiosulfate.

In order to avoid a build-up of impurities in the treated wastewater, a 20 percent blowdown is planned (54,000 gpd).

Decolored wastewater is filtered to remove particulates of 15 microns or larger that may contain additional color. The treated waste-

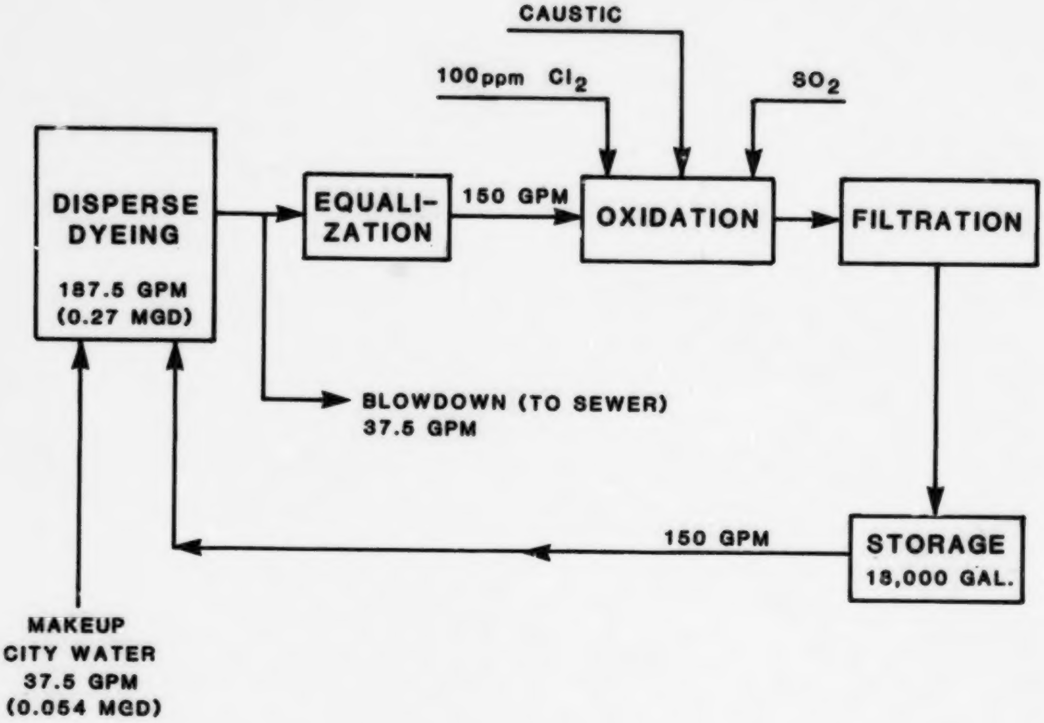

CAUSTIC
100ppm Cl2
SO2
DISPERSE DYEING
187.5 GPM
(0.27 MGD)
EQUALI-ZATION
150 GPM
OXIDATION
FILTRATION
BLOWDOWN (TO SEWER)
37.5 GPM
150 GPM
STORAGE
18,000 GAL.
MAKEUP
CITY WATER
37.5 GPM
(0.054 MGD)

FIGURE IV-1. SCHEMATIC DIAGRAM OF DYE WASTEWATER DECOLORIZATION AND RECYCLE

TABLE IV-1

DYE WASTEWATER CHARACTERIZATION

	Concentration, mg/l		
Alkalinity	170	10	0
Acidity	0	0	180
pH (SU)	10.4	5.0	4.8
BOD	200	300	1,700
COD	830	2,000	11,000
TS	420	20,000	2,900
TDS	240	670	3,300
TSS	9	33	30
Chloride	10	9.5	25
Oil & Grease	8,900	63	19
Phenolics	0.04	0.79	22.0
Turbidity (NTU)	125	190	1,700
Color (ADMI)	1,100	3,500	15,200
Calcium	2.4	2.6	8.8
Magnesium	1.7	2.0	3.5
Sodium	100	60	230
Chromium	< 0.2	< 0.2	< 0.2
Copper	< 0.2	< 0.2	< 0.2
Iron	1.5	0.89	1.5
Lead	< 0.2	< 0.2	< 0.2
Manganese	< 0.1	< 0.1	0.22
Nickel	< 0.1	< 0.1	< 0.1
Zinc	0.12	0.12	0.30
Temperature (°F)	101	106	211

Source: Wastewater samples taken March 15 to 18, 1982.

water is stored briefly before returning to the dyeing machines for dyebath makeup and for overflow rinsing. The final rinse of the goods would be with city water.

Since the wastewater has been decolored and filtered, there should be no problem with reuse for dyeing and thus, recycle should not affect the mill's need to maintain flexibility in dyeing schedules as with reconstitution (see Section III). The quality of the water expected is discussed in more detail under Technical Feasibility.

Since it is expected that the chlorine oxidation system will require 1,000 to 3,000 square feet, it is envisioned that it will need to be located outside the dyehouse.

TECHNICAL FEASIBILITY

Literature and Previous Applications

Investigation by Perkins et al. (Reference 4) and Textile Systems, Inc. (TSI) have demonstrated that disperse dyes can be decolored by chemical oxidation. Both ozone and chlorine have been successful in producing a water suitable for reuse in dyeing, and test dyeings over a series of reuse applications have been acceptable.

Oxidation has been shown to decrease the molecular weight of dye molecules by attacking amide and other molecular linkages, thereby destroying chromophoric groups and decoloring the wastewater.

Thus far, only oxidation by chlorine has been employed in full-scale applications for dye wastewater decolorization, and this has been primarily for acid dyes. Ozone has not been applied because of costs of generation, practicality, and safety hazards, but it may become more competitive as improvements are made.

A more detailed summary of the research and applications to date is found in Volume 1.

Bench Scale Results

A composite sample of dyes and rinses was collected, and a bench scale chlorination test was conducted. The test indicated that while the dyes encountered in the sample were substantially decolored by chlorination, complete decolorization could not be achieved, even at very high dosages near 2500 mg/l Cl_2.

It is likely that the composite was not representative of the dyes normally used at the mill, because the pH was above 10, as opposed to a typical dyebath of pH 5.

Therefore, the results are not considered to be conclusive enough for demonstrating the technical feasibility of chlorine decolorization at this mill, and more extensive and controlled studies need to be conducted to determine the dyes that are amenable to chlorine decolorization and the expected dosage requirements.

TECHNICAL DESIGN CRITERIA

The criteria developed in previous investigations by Perkins et al. and TSI dictate a chlorine dose of 100 mg/l applied for about 30 minutes for adequate decolorization of disperse dye wastewater. Sulfur dioxide is used to reduce the residual chlorine, and liquid caustic is used to adjust the pH to about 8.0.

The system is sized to treat about 270,000 gpd. With a small safety factor, the standard system provided by TSI for 200 gpm is expected to be adequate.

Treatment tank capacity needs to be about three times the capacity for acid dye wastewaters, due to the slower reaction time for disperse dyes. Thus, the volume of the treatment tanks is about 27,000 gallons, based on 3 hours at 9,000 gallons per hour.

Storage capacity for about two hours of average flow is typically suggested, which would result in a volume of 18,000 gallons.

Design criteria are summarized in Table IV-2.

ECONOMIC FEASIBILITY

Cost savings are realized in the areas of water use, wastewater discharge, COD surcharge, and auxiliary chemical use. Additional operating costs will be encountered both for labor and chemicals for the oxidation/recycle process.

TABLE IV-2
DESIGN CRITERIA
DYEBATH OXIDATION/RECYCLE

Oxidation		
Reaction Time	minutes	30
Chlorine Dose	mg/l	100
	lb/day	185
Reaction pH		8.0
Caustic Feed	lb/day	650
Dechlorination		
Sulfur Dioxide Dose	mg/l	90
	lb/day	165
Reaction Time	minutes	5
Total Treatment Capacity		
	gallons	27,000
	hours @ avg. flow	3
Storage Capacity		
	gallons	18,000
	hours @ avg. flow	2
Hydraulic		
Flow (average)	gpm	150
	mgd	0.22
Design Flow	gpm	200

Table IV-3 presents an analysis of the annual cost savings realized through dyebath oxidation and recycle. The basis for these costs and savings is as follows:

- Water and wastewater (volume) savings of $0.83 per 1,000 gallons.
- Wastewater surcharge savings of 3.3 cents per pound of COD, for COD > 600 mg/l.
- Auxiliary (dyeing) chemical costs of $0.022 per pound of fabric dyed.
- Treatment chemical costs of:

chlorine	8¢/lb
caustic	27¢/lb
SO_2	15¢/lb

- Treatment labor requirement is 4 man-years.
- Capital costs are explained in Volume 1.

Other assumptions include the following:

- Water use savings are 80 percent, based on 20 percent recycle.
- Auxiliary chemical savings are 50 percent, COD reduction is 50 percent.
- No energy benefit is realized due to existing heat exchangers.
- Treatment chemical requirements are as given in Table IV-2.
- Dyehouse operates 250 days/year.

The estimated capital cost (June 1982) of an oxidation recycle system is $430,000, including costs for the reaction and storage tanks, chemical feed and control systems, piping, pumps, electrical service, and engineering costs. The resulting payback period is 4.7 years, based on the annual operating savings of $92,000.

TABLE IV-3
OPERATING SAVINGS FOR DYEBATH OXIDATION/RECYCLE

Water/Wastewater	(gpd)	216,000
	($/yr)	45,000
COD Surcharge	(lb/day)	1,600
	($/yr)	4,000
Auxiliary Chemicals	($/yr)	172,000
Energy Savings	($/yr)	0
Oxidation Process Chemicals	($/yr)	(54,000)
Oxidation Process Labor	($/yr)	(75,000)
Net Annual Savings	($/yr)	92,000

ENVIRONMENTAL EFFECTS

The introduction of dyebath oxidation and recycle would result in a decreased wastewater discharge of 216,000 gpd, or almost 30 percent of the plant total. In addition, the daily average discharge of COD would be reduced by 1,600 pounds, 23 percent of the plant total.

One area that requires further investigation is whether chlorinated organic compounds are formed during the chlorination process.

CONCLUSIONS

- The literature indicates that dyebath oxidation and recycle should be amenable to the dyeing operations at this plant.
- Bench scale tests indicated decoloring of the composite dyebath, but the tests are not considered as conclusive.
- Significant environmental benefits may be realized by recycle, but the potential formation of chlorinated organic compounds should be investigated.
- Testing should confirm that decolored dye wastewater can be reused without adversely affecting the quality of the dyeing
- The economics of chlorine oxidation do not appear favorable at this mill because of high capital costs and the relatively low value of recoverable chemicals. The fact that energy is not recovered because of an existing heat exchanger also detracts from the economic attractiveness of the technology. It is generally recognized that economies of scale can be realized, and equipment manufacturers usually recommend the system be considered for flows greater than 500,000 gpd.

SECTION V

REUSE OF WATER JET WEAVING WASTEWATER

DESCRIPTION OF MANUFACTURING PROCESS

Water Use and Wastewater Characteristics

A softened water supply of about 150,000 gpd is used in the operation of the water jet looms. The resultant wastewater is slightly contaminated with acrylic size and oils. Samples of the wastewater were collected and analyzed, and the results are shown in Table V-1. The flow schematic of the current water jet weaving process is presented in Figure V-1.

Two alternatives are worthy of consideration for reuse of this wastewater. The first would be complete recycle/reuse with direct reuse of 67 percent of the water at the water jet looms, and the remaining 33 percent at the scour/desize washers. The second alternative is partial recycle/reuse with 50 percent of the water reused at the scour/desize washers; the remaining 50 percent is sewered.

EVALUATION OF THE POTENTIAL FOR REUSE

Technical Feasibility

Alternative 1 - Reuse in water jet weaving. The scheme under this alternative is illustrated in Figure V-2. Under this alternative, about 2/3 (100,000 gpd) of the wastewater would be continuously recycled to the water jet looms with the other 1/3 (50,000 gpd) reused at the scour/desize washers to avoid buildup of oils and solids in the water jet weaving water supply. This amount would be made up with softened and chilled clean water. This alternative would reduce the operation and maintenance of the softeners, because it is expected on the basis of the analytical results that hardness will not build up in the wastewater and repeat softening will not be required. Furthermore, the requirements for chilled water during summer months would also be reduced.

Reuse of this water in the desize/scour washers appears to be technically feasible based on a comparison of the water jet weaving wastewater with the effluent from the washers:

TABLE V-1
WATER JET WEAVING
FEED AND WASTEWATER CHARACTERIZATION

	Concentration (mg/l)	
	Softened Water	Water Jet Wastewater
pH (S.U.)	7.5	6.5 to 7.1
Color (ADMI)	6	80
BOD	-	12
COD	16	180
TSS	-	4
TDS	220	71
Turbidity (NTU)	0.2	32
Phenolics	0.001	0.061
Chloride	9.6	9.2
Alkalinity	10	14
Calcium	1.2	1.2
Magnesium	1.1	1.2
Sodium	25	28
Chromium	< 0.2	< 0.2
Copper	< 0.2	< 0.2
Iron	0.55	0.9
Lead	< 0.2	< 0.2
Manganese	< 0.1	< 0.1
Nickel	< 0.1	< 0.1
Zinc	0.11	< 0.1
Oil & Grease	-	48
Temperature (°F)	54	63

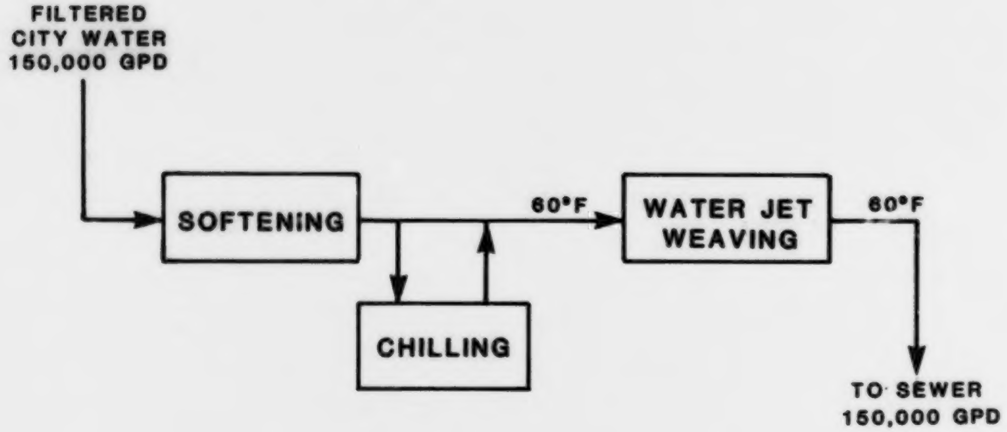

FILTERED
CITY WATER
150,000 GPD
SOFTENING
CHILLING
60°F
WATER JET
WEAVING
60°F
TO SEWER
150,000 GPD

FIGURE V-1. CURRENT WATER JET WEAVING SCHEMATIC

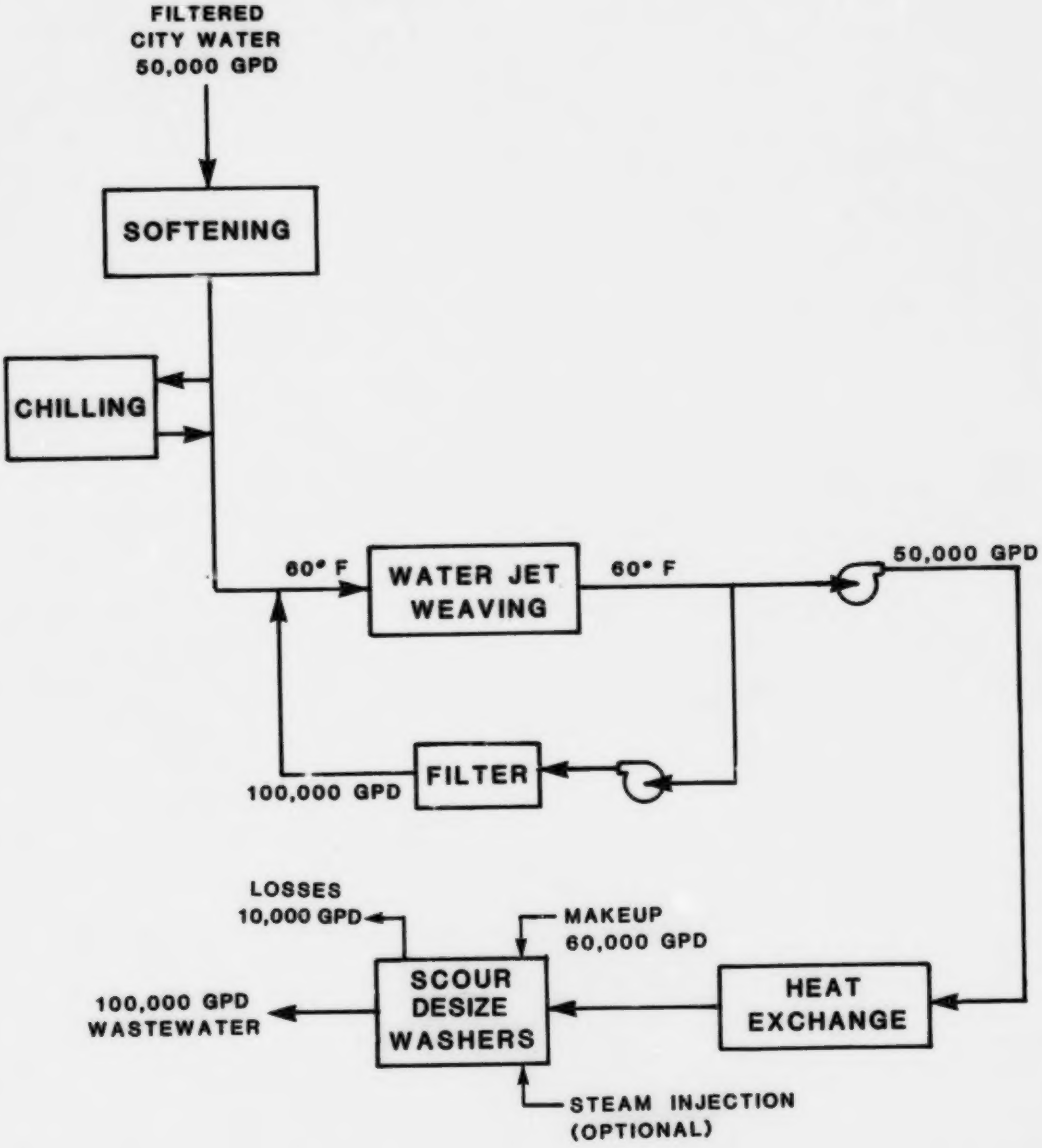

FILTERED
CITY WATER
50,000 GPD
SOFTENING
CHILLING
60° F
WATER JET WEAVING
60° F
50,000 GPD
FILTER
100,000 GPD
LOSSES
10,000 GPD
MAKEUP
60,000 GPD
SCOUR DESIZE WASHERS
HEAT EXCHANGE
100,000 GPD
WASTEWATER
STEAM INJECTION
(OPTIONAL)

FIGURE V-2. RECYCLE ALTERNATIVE 1 WATER JET WEAVING WASTEWATER

	Concentration, mg/l		
	Water Jet Weaving	Scouring	Desizing
BOD	12	86	660
COD	180	1,250	2,600
TDS	71	160	5,110
TSS	4	5	95
Oil & Grease	48	122	93

As noted previously, the water jet weaving wastewater contains only small amounts of size and oils from the weaving process, the same constituents being removed during washing. The temperature of the water jet weaving wastewater will have to be raised to 130 or 175°F for scouring or desizing from 60°F, as compared to the current situation in which city water (assumed yearly average temperature of 70°F) is heated to these temperatures.

For reuse in weaving, the small amount of size in the water is not considered to be detrimental. The suspended solids concentration is also very low. One obstacle to this scheme is the inconsistency of the wastewater oil content. The range of the oil concentration is due to inconsistent housekeeping practices that allow machine oils to be discharged to the wastewater. These oils would likely damage the incoming fibers. For this reason, the scheme includes an optional cartridge type filter for use when machine oil spills are observed.

Alternative 2 - Reuse at the scour/desize washers. Mill personnel have been hesitant to reuse the water jet weaving wastewater directly at the looms, mostly because of the potential oils and solids problems. Therefore, an alternative scheme, as illustrated in Figure V-3, would be to reuse the wastewater only at the scour/desize washers. It is expected that about 75,000 gpd could be safely reused at the washers, as discussed above, using about 35,000 gpd of clean makeup water. The remaining 75,000 gpd of water jet weaving wastewater would be sewered.

In order to preheat the water from water jet weaving, the water would be passed through heat exchangers. Since the water jet water must be maintained around 60°F, the mill would again have to expend additional energy to chill and heat the water during the warmer season when incoming city water is often at a temperature above 80°F.

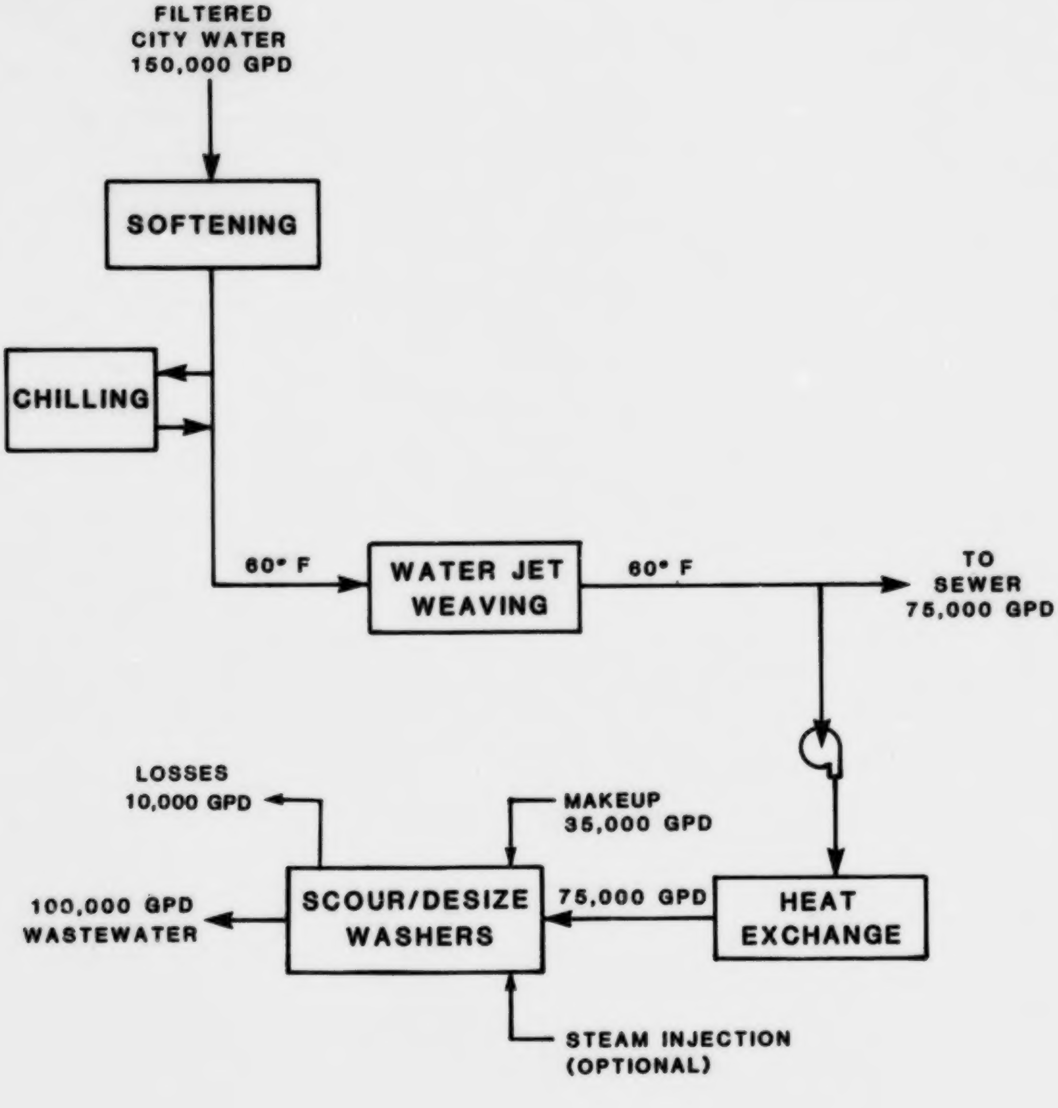

FILTERED
CITY WATER
150,000 GPD
SOFTENING
CHILLING
60° F
WATER JET
WEAVING
60° F
TO
SEWER
75,000 GPD
LOSSES
10,000 GPD
MAKEUP
35,000 GPD
100,000 GPD
WASTEWATER
SCOUR/DESIZE
WASHERS
75,000 GPD
HEAT
EXCHANGE
STEAM INJECTION
(OPTIONAL)

FIGURE V-3. RECYCLE ALTERNATIVE 2 WATER JET WEAVING WASTEWATER

Economic Feasibility

Recycle of water jet weaving wastewater to the looms results in cost savings in the area of water use, wastewater discharge, water softening, and water chilling. Reuse at the desize/scour washers results in water use savings, wastewater discharge savings, but slightly greater costs in water heating due to the 60°F temperature of the weaving wastewater. Operating costs and savings were developed for the two alternatives just discussed:

Case 1. Recycle to looms and desize/scour washers.
Case 2. Recycle only to desize/scour washers.

The basis for the costs and savings are as follows:

- Water and wastewater (volume) savings of \$0.83 per 1,000 gallons.
- Wastewater surcharge of 3.3 cents per pound of COD, for COD > 600 mg/l.
- Water softening costs of 0.6 cents per 1,000 gallons (chemical cost).
- Water chilling cost of \$1 per ton-day based on electricity at \$0.042/KWH and 1 KW/ton cooling.
- Water heating costs of \$4.30 per million BTU.

Other assumptions include the following:

- Weaving is performed 312 days/year.
- Desizing/scouring is performed 250 days/year.
- Heating efficiency is 90 percent (hot water).
- Annual average city water temperature is 70°F, requiring 10°F cooling.

Table V-2 presents an analysis of these operating costs and savings.

Note that the COD surcharge actually increases due to recycle. This is because the reduced wastewater volume also reduces the amount of COD exempt from the surcharge.

TABLE V-2
OPERATING SAVINGS
WATER JET WEAVING WASTEWATER REUSE

	Case 1	Case 2
Water Savings (gal/day)	150,000	75,000
($/yr)	38,800	19,400
COD Surcharge ($/yr)	(7,800)	(4,100)
Softened Water Savings (gal/day)	100,000	0
($/yr)	200	0
Chilled Water Savings (tons cooling)	29	0
($/yr)	9,000	0
Energy Cost (Reheating) (10^6BTU/day)	4.2	6.3
($/yr)	(5,000)	(7,500)
Net Annual Savings ($/yr)	$35,200	$7,800

Estimated capital costs (June 1982) and the resulting payback periods for these two cases are as follows:

	Capital Cost	Annual Savings	Payback (years)
Case 1	$26,000	$35,200	0.7
Case 2	$22,000	$ 7,800	2.8

The capital costs include a storage basin, pumps and piping, electrical service to the pumps, cartridge filter, and engineering costs. It is conceivable that the expense of piping installation may be more than envisioned in the capital costs estimated above due to unknown underground obstacles and other difficulties.

As indicated on Table V-2, the major cost savings result from water savings. Despite the lack of chemical value in the wastewater, reuse of the total flow shows much economic promise. A detailed evaluation of the piping and pumping needs should be performed to more closely estimate the capital costs, especially since piping and pumping are the major capital costs involved in the system.

ENVIRONMENTAL EFFECTS

As discussed in Section I of this report, water jet weaving represents a sizeable fraction of the mill's wastewater flow, but only a few percent of the pollutant load. Recycle and reuse of this stream, as described above, would result in the elimination of from 75,000 to 100,000 gpd wastewater. This represents approximately 10 to 14 percent of the total wastewater flow.

CONCLUSIONS

- Recycle of the total flow of water jet weaving wastewater appear to be technically and economically feasible, but capital costs for piping and pumping need to be investigated in more detail.

- The poor economics of partial reuse are due to the fact that the wastewater contains little or no reusable chemical value or heat value, and the reuse of about half the flow does not provide enough water savings.
- Testing must be performed to ascertain that the water jet weaving wastewater can be reused without causing damage to the looms and the fabrics. This testing should include testing of in-line filters for removal of oils.
- The mill should be attentive to controlling the entry of machine oils in the wastewater. An employee education program could be geared toward promoting general good housekeeping procedures around the looms.

SECTION VI

RECOVERY OF TEREPHTHALIC ACID FROM DENIER REDUCTION WASTEWATER

DESCRIPTION OF MANUFACTURING PROCESS AND APPLICABLE RECYCLE/REUSE METHOD

Denier reduction is a batch process that reduces the weight of the polyester fabrics by means of a caustic treatment prior to dyeing. The objective is to produce a "synthetic silk" product. In this process, the constituents of the polyester fabric are broken down to terephthalic acid, ethylene glycol, and other by-products. The resulting wastewater generally has a high COD and pH and contains 1 to 1.5% terephthalic acid. Table VI-1 presents the results of wastewater analyses of this stream.

The frequency with which the process is performed varies each week, and mill personnel report a range of denier reduction wastewater discharge from 6,000 to 35,000 gallons per week.

The mill is interested in recovering and marketing the terephthalic acid. The method for recovery, as illustrated in Figure VI-1, involves a pH adjustment to about pH 4.5 to precipitate all the dissolved terephthalic acid (TPA). Subsequently, the supernatant must be decanted and the TPA dewatered. The resulting powdered TPA solids likely will not be pure enough for reuse in fiber manufacturing, because 99.9 percent purity is required (Reference 3). There is a possibility that it could be purified enough to be used in the manufacture of alkyd resins, but the product must be very low in metals content (less than 2 ppm) for this use. Sodium may be a problem, because the TPA is dissolved in the caustic bath used in denier reduction.

The oil well service industry uses a variety of acids in formation, stimulation and fracturing, and the mill sees this as a possible market (Reference 2).

TECHNICAL FEASIBILITY

The method of treatment to recover TPA will depend on the requirements of the market. The preliminary design is subject to much revision and testing, but it is presented to provide a rough idea of the

TABLE VI-1
WASTEWATER CHARACTERISTICS
DENIER REDUCTION

	Concentration (mg/l)
Alkalinity (as $CaCO_3$)	9,900
BOD	13,000
COD	31,000
TS	22,000
TSS	810
Turbidity (NTU)	1,000
Chloride	170
Oil & Grease	< 2.5
Phenolics	0.017
Calcium	2.0
Magnesium	1.0
Sodium	5,400
Chromium	< 0.2
Copper	< 0.2
Iron	0.35
Lead	< 0.2
Manganese	0.26
Nickel	0.12
Zinc	0.16
pH (S.U.)	12.0
Temperature (°F)	200

Source: Wastewater sample collected March 16, 1982.

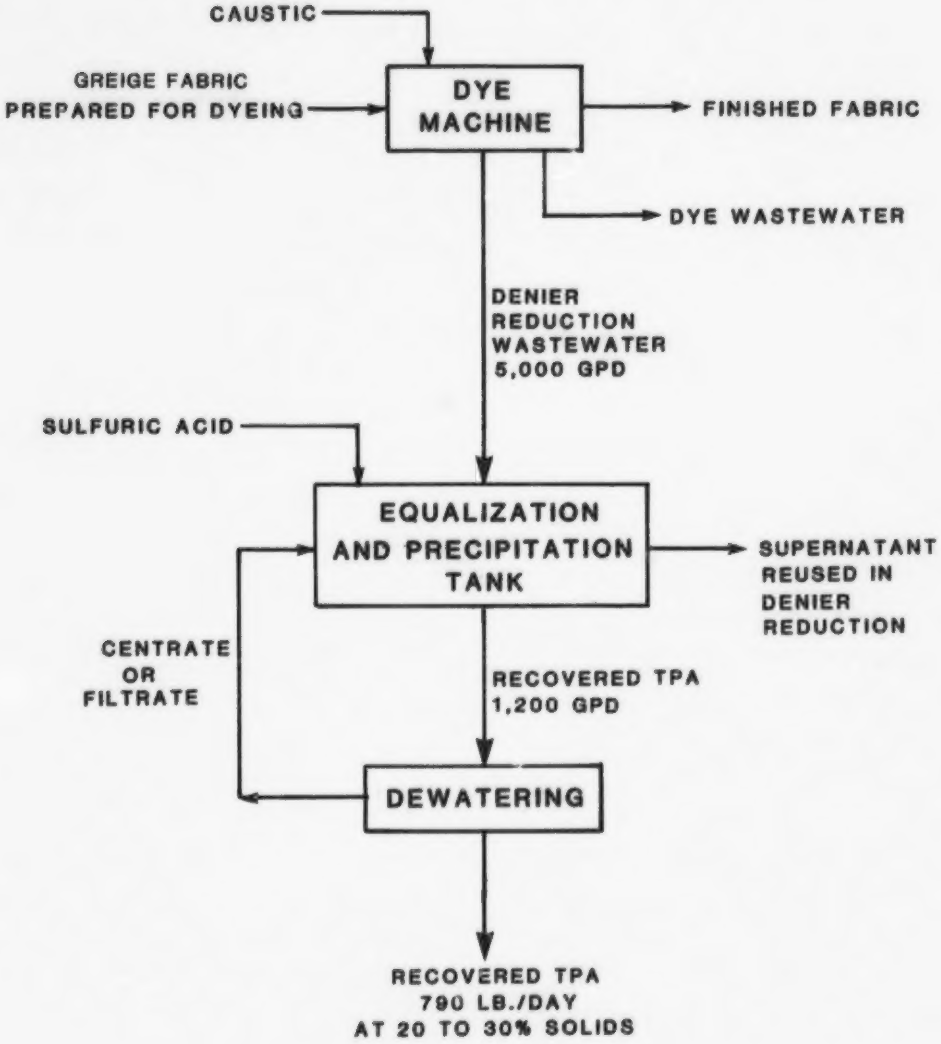

CAUSTIC
GREIGE FABRIC PREPARED FOR DYEING
DYE MACHINE
FINISHED FABRIC
DYE WASTEWATER
DENIER REDUCTION WASTEWATER 5,000 GPD
SULFURIC ACID
EQUALIZATION AND PRECIPITATION TANK
SUPERNATANT REUSED IN DENIER REDUCTION
CENTRATE OR FILTRATE
RECOVERED TPA 1,200 GPD
DEWATERING
RECOVERED TPA 790 LB./DAY AT 20 TO 30% SOLIDS

FIGURE VI-1. TEREPHTHALIC ACID RECOVERY SYSTEM

costs of TPA recovery and the approximate range of breakeven prices for the recovered product. The basic scheme, as illustrated in Figure VI-1, is to adjust the pH to about 4.5 with sulfuric acid. A bench scale test inidicated that this will precipitate the terephthalic acid, leaving a clear ($<$1.0 NTU turbidity), colorless supernatant. The supernatant, however contains a very high level (5,100 mg/l) dissolved solids due to the caustic used in denier reduction and the acid used for neutralization. This rapid buildup of dissolved solids would limit the number of reuse cycles of the supernatant to probably 2 or 3.

The use of acidic dye wastewater was also considered for neutralization, but this is judged as not feasible due to the low amount of acidity in the dye wastewater (180 mg/l) compared to the alkalinity (9,900 mg/l) of the denier reduction wastewater.

The settled solids resulting from precipitation will have to be dewatered, the degree depending on market requirements, such as moisture content and hauling costs. A centrifuge or filter press would be used for dewatering.

ECONOMIC FEASIBILITY

The amount of terephthalic acid that can be recovered from the wastewater is estimated to range from 200 to 1,100 pounds per day, with an average of 790 pounds. Based on an estimated maximum value of 20 cents/pound, the annual value of recovered TPA is only $40,000. Water and energy savings total $4,000 per year, and the COD surcharge is lowered by $10,000.

Operating costs are estimated at $4,000 annually for sulfuric acid neutralization and $10,000 for TPA dewatering. Thus, the net annual savings is $40,000.

The capital costs for acid feed and dewatering equipment could easily exceed $100,000, with most of this amount for dewatering. Thus, even with an optimistic estimate of the value of the recovered TPA, the payback period is at least 2.5 years.

ENVIRONMENTAL EFFECTS

The reuse of denier reduction wastewater following removal of the terephthalic acid would have little effect on the total volume of wastewater discharge from the plant (i.e., less than 1 percent reduction). The amount of COD reduction, however, is significant, estimated at an maximum of 1,300 lb/day, or about 19 percent of the plant total. Note, however, that during our field investigation, the denier reduction wastewater accounted for only 4 percent of the total COD (see Section I).

CONCLUSIONS

- Technically, the recovery of terephthalic acid from denier reduction wastewater is a relatively simple operation consisting of batch precipitation, decanting, and dewatering.
- Economically, the uncertainty of a specific market and value for the recovered product, along with the small amount of product involved, make this technology look unpromising.

REFERENCES

1. Groves, G. R., G. L. Dalton, and C. A. Buckley. "Textile Size and Water Recovery by Means of Ultrafiltration," presented at the International Conference on Advanced Treatment and Reclamation of Wastewater, 1977.

2. Halliburton Services, personal correspondence.

3. HERCO FWA, manufacturer of terephthalic acid, personal correspondence.

4. Perkins, W. S., J. F. Judkins, Jr., and W. D. Perry. "Renovation of Dyebath Water by Chlorination or Ozonation," Textile Chemist and Colorist, Vol. 12, Nos. 8-10 (August-October, 1980), pp. 182-272.

5. Tincher, Wayne C., F. L. Cook, and L. A. Barch. "Reusing Dyebaths in Jet Dyeing," Textile Chemist and Colorist, Vol. 13, No. 12 (December 1981), pp. 266-269.

APPENDIX A

Report on Bench Scale Ultrafiltration Tests Conducted by Gaston County Filtration Systems - Lab Engineer - David Boyles.

Summary:

Gaston County Filtration System (GCFS) conducted a series of bench scale tests of their ultrafiltration system to demonstrate the ability to separate phases in the following wastewater streams:

1) Scour wastewater - oil separation (3/15/82)
2) Desize wastewater - size and oil separation (3/18/82)
3) Denier reduction wastewater - terephthalic acid separation (3/15 & 3/22/82)

Separation was achieved for the scour and desize wastewater, while the denier reduction wastewater required pH adjustment to approximately 4.5 to achieve separation. The pH adjustment causes the terephthalic acid to precipitate, so that the UF system functioned actually as a concentration method rather than separation method.

DESCRIPTION OF THE BENCH SCALE UF UNIT

The GCFS portable bench scale UF unit consists of a single loop system with pump, zirconium oxide membrane installed in a UF module, and piping to allow for concentrate recycle and permeate discharge until desired TS levels are found in the concentrate.

The zirconium oxide membrane is capable of withstanding a wide pH and temperature range without fouling problems.

All tests were conducted on samples with their temperature brought up to the approximate temperature of the process, i.e., 180°F for scour/desize wastewater, 200°F for denier reduction wastewater.

PILOT SCALE TESTING

GCFS can conduct pilot scale testing of a UF unit for a minimum period of six weeks, and a cost of about $350.00 per week.

MILL SURVEY REPORT
MILL W-8
WOVEN INDUSTRIAL FABRIC FINISHER

SUMMARY

Mill W-8, a commission finisher of woven fabrics, uses several manufacturing processes that have been investigated in this study for the potential applicability of wastewater recycle/reuse methods. Figure 1 illustrates the basic processes, summarizes the findings, and identifies further research needs. Table 1 summarizes the projected savings, costs, and paybacks associated with the recycle/reuse methods considered at this mill.

The most promising recycle/reuse techniques at this mill are:

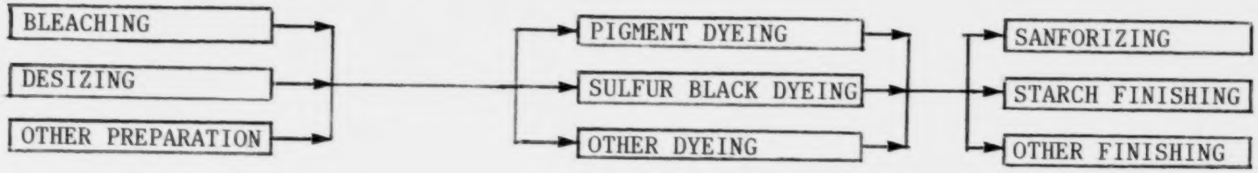
1. Countercurrent rinsing and/or water use reduction on the rope washers, open width desize range, and sulfur black dye range.
2. Dye recovery by hyperfiltration at the sulfur black dye range.

RECOMMENDATIONS

It is recommended that the following techniques and research needs be pursued for recycle/reuse of wastewater at this mill:

1. Countercurrent rinsing and water use reduction should be tested to determine effects on fabric quality and manufacturing processes at the rope washers, desize range, sulfur black dye range, and possibly other preparation ranges not investigated in this study.
2. Pilot tests of hyperfiltration at the sulfur black dye range should be conducted to confirm the technical and economic feasibility of the technology. In particular, the following research efforts should be undertaken:
    a. Determine the actual quantity of dye that can be recovered.
    b. Confirm the suitability of reusing the recovered dye.
    c. Confirm the suitability of permeate for reuse.
    d. Examine the buildup of impurities in the recovered dye and the permeate to determine the necessary blowdown.

MILL W-8


BLEACHING
DESIZING
OTHER PREPARATION
PIGMENT DYEING
SULFUR BLACK DYEING
OTHER DYEING
SANFORIZING
STARCH FINISHING
OTHER FINISHING

Technologies Evaluated	Feasibility Technical	 Economic	Data Needs
Rope Bleachery			
Countercurrent Rinsing	Feasible	Promising	Testing
Desize Range			
Countercurrent Rinsing	Feasible	Promising	Testing
Size Recovery by Hyper/Ultrafiltration	Not Promising	Not Promising	--
Sulfur Black Dye Range			
Countercurrent Rinsing	Feasible	Promising	Testing
Sulfur Black Dye Recovery by Hyperfiltration	Feasible	Promising	Pilot Scale Test

FIGURE 1

TABLE 1

SUMMARY OF ECONOMIC AND ENVIRONMENTAL
BENEFITS OF VARIOUS RECYCLE SCHEMES

Recycle/Reuse Scheme	Net Annual Savings (Costs)	Capital Cost	Payback (Years)	Flow Reduction		BOD Reduction	
				gpd	% total	lb/day	% total
Countercurrent Rinsing at Rope Bleachery	$ 43,000	-0-	Immediate	85,000	22	-0-	-0-
Desize Range - Countercurrent Rinsing	$ 1,000	-0-	Immediate	5,000	1	-0-	-0-
Size Recovery(1)	--	--	--	--	--	--	--
Sulfur Black Dye Range - Countercurrent Rinsing/Flow Reduction	$ 2,000	-0-	Immediate	8,000	2	-0-	-0-
Dye Recovery	$158,000	$470,000	3.0	29,000	7	960	9

(1) Determined to be technically unfeasible

TABLE OF CONTENTS

Page

Summary ii

Table of Contents v

I. INTRODUCTION 1
  - Facility Description. 1
  - Manufacturing Processes 3
  - Overall Mass Balance. 4
  - Evaluation of Recycle and Reuse Technologies. 8

II. ROPE BLEACHERY 13
  - Description of Manufacturing Process. 13
  - Evaluation of the Potential for Reuse 13
  - Environmental Effects 16
  - Conclusions 16

III. SIZE RECOVERY BY ULTRAFILTRATION/HYPERFILTRATION 18
  - Description of Manufacturing Process. 18
  - Evaluation of the Potential for Reuse 18
  - Environmental Effects 23
  - Conclusions 23

IV. SULFUR BLACK DYEING - DYE RECOVERY BY HYPERFILTRATION. 25
  - Description of Manufacturing Process. 25
  - Proposed Modification of the Dye Range Operation for Reuse 28
  - Technical Feasibility 28
  - Economic Feasibility. 30
  - Environmental Effects 32
  - Conclusions 32

Appendix A 33

SECTION I

INTRODUCTION

Recycling and reusing process wastewater can be an important method for reducing the quantity of pollutants discharged from textile mills. Of equal importance to the textile industry, recycle and reuse can save money by recovering process chemicals, saving hot water, and lowering the sewer use charges of indirect dischargers. Recycle and reuse are not yet in wide-spread use, though in recent years, recycle and reuse technologies have been gaining recognition as a method to save money as well as reduce the discharge of pollutants. In order to encourage this development further, this report examines the technical and economic feasibility of recycle and reuse technology at Mill W-8, a woven fabric finishing mill.

The report begins with a description of the production processes, products, and material balances at Mill W-8. The feasibility and the economics of countercurrent rinsing and membrane filtration for several in-plant wastewater streams are then considered.

FACILITY DESCRIPTION

Mill W-8 is a commission finisher of woven industrial fabrics, interlining, and pocket fabric. The mill processes a large quantity of imported fabric, mainly cotton/polyester and polyester/rayon blends. The production processes, shown in Figure I-1, include bleaching, desizing, dyeing, and finishing. Sixty-five percent of the greige fabric received at the mill is sized with starch, while 30 percent is sized with synthetic materials, such as PVA and CMC. The remaining five percent is not sized.

The major wet finishing operations are bleaching, desizing, and continuous dyeing. The wastewater from these operations passes through a heat exchanger to preheat plant make-up water and then is neutralized and discharged to the municipal sewer. Live steam from a coal-fired boiler is also used to heat plant make-up water.

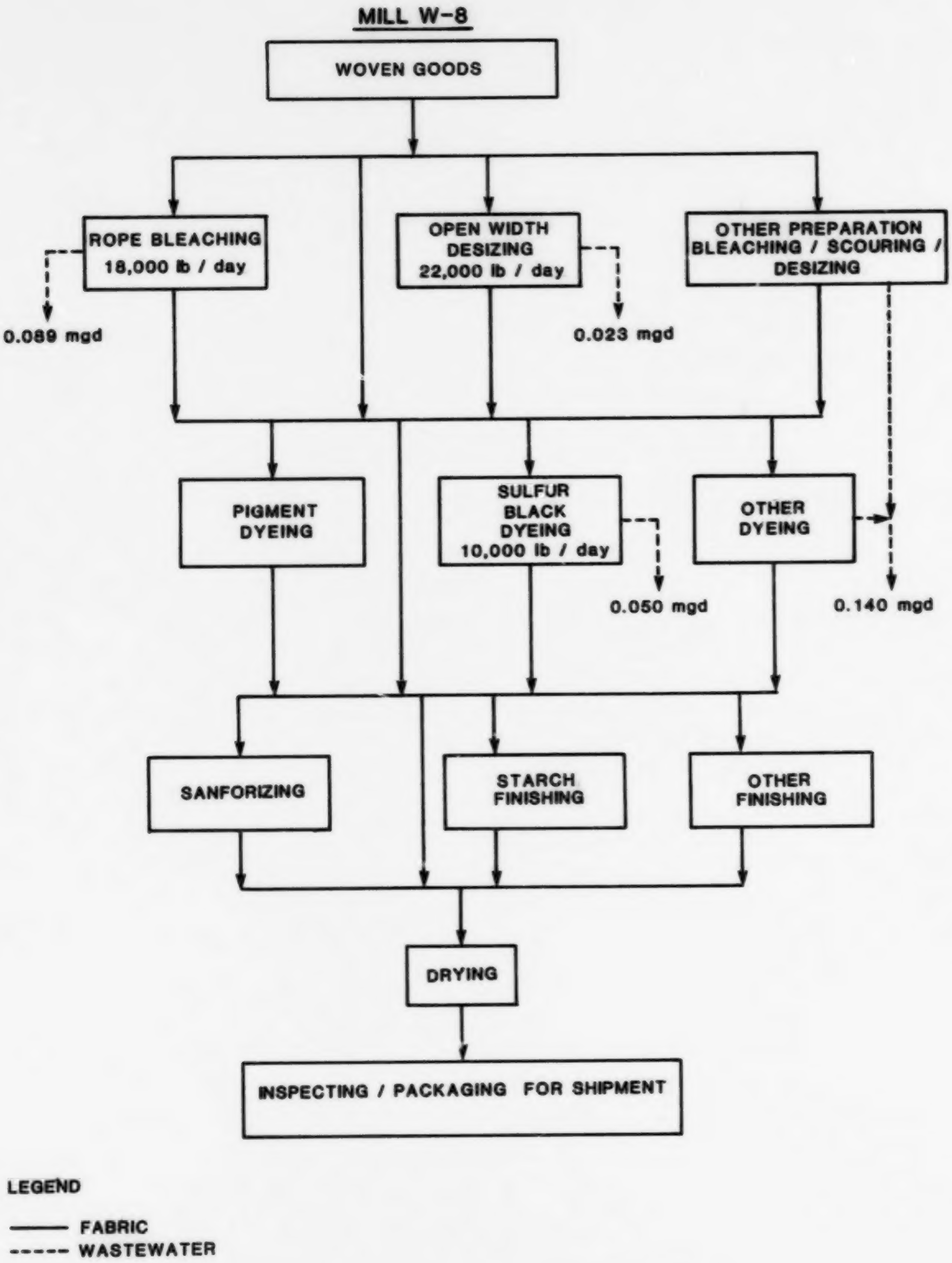

MILL W-8
WOVEN GOODS
ROPE BLEACHING
18,000 lb / day
0.089 mgd
OPEN WIDTH
DESIZING
22,000 lb / day
0.023 mgd
OTHER PREPARATION
BLEACHING / SCOURING /
DESIZING
PIGMENT
DYEING
SULFUR
BLACK
DYEING
10,000 lb / day
0.050 mgd
OTHER
DYEING
0.140 mgd
SANFORIZING
STARCH
FINISHING
OTHER
FINISHING
DRYING
INSPECTING / PACKAGING FOR SHIPMENT
LEGEND
FABRIC
WASTEWATER

FIGURE I -1 MANUFACTURING PROCESSES

MANUFACTURING PROCESSES

Bleaching

Two rope bleach ranges saturate cotton/polyester fabric with caustic and peroxide in the first stage of the bleaching operation. Subsequently, the fabric passes through three or four rope washers. The continuous flow in the washers is maintained at about 180°F and pH 9.3. The mill has countercurrent rinse capability on these ranges and uses it occasionally.

The rope bleach ranges are described further in the section on recycle/reuse technologies for the bleachery.

Desizing

Starch-sized fabric is desized with enzymes on open width ranges, which may also perform scouring and/or bleaching, depending on the fabric. The fabric is saturated with an enzyme solution, retained in a J-box for about two minutes, and rinsed thoroughly with hot water. The rinsing occurs in a series of eight open width rinse boxes. The temperature in the boxes varies from 120°F to 200°F. Make-up water for the rinse system is preheated to 120°F through the mill's heat exchange system. Live steam is added to each box when desired. The range is capable of countercurrent rinsing, and this is sometimes done.

The desize ranges are discussed further in the section on recycle/reuse technologies for the desizing operation.

Dyeing

The mill performs pigment dyeing, sulfur black dyeing, and other continuous dyeing, with percentages of production varying with market demands. Typically the pigment dyeing process comprises 50 percent of the mill's dyeing and produces no process wastewater. The fabric dyeing of most interest to this study is sulfur black dyeing. This is because of the large amount of sulfur black dyeing performed at the mill, and the consequent potential for dye recovery and reuse. On the continuous sulfur black dye range, the fabric passes through a dye pad followed by a steamer, water seal and nip, six rinse boxes, brine (oxidation) bath, and three more rinse boxes. The mill generally uses countercurrent rinsing on this range.

This dye range is described further in the section on recycle/reuse technologies for the dye range.

Finishing

The mill performs a variety of finishing processes including sanforizing and starch finishing. In the starch finishing process, the mill uses a fairly dilute starch and talc suspension in what they refer to as a "backfilling" operation, with starch/talc serving as a "hand building" agent. The mill is interested in recovering starch from desizing for use in this finishing operation. Other details of the operation are considered proprietary. The finishing processes do not discharge a significant flow or pollutant load.

OVERALL MASS BALANCE

Water Use and Characteristics

Figure I-2 depicts the water balance at Mill W-8. Total water use at the mill averages about 460,000 gpd. Three major wet processes are rope bleaching (103,000 gpd), open width desizing (27,000 gpd) and sulfur black dyeing (55,000 gpd). The balance of water use consists of other preparation and dyeing operations, utilities, and other miscellaneous uses.

Table I-1 indicates the water use rates of the three major waste streams in terms of gallons per pound. The sulfur black dye range uses about 5 gal/lb of product, the desizing range uses about 1 gal/lb, while the rope bleachery uses about 6 gal/lb. Table I-2 lists the quality of the incoming city water.

Wastewater Discharge and Characteristics

About 85 percent of the incoming water is discharged (387,000 gpd) as shown in Figure I-2. About 15 percent is lost or retained in the fabric after wet processing.

MILL W-8

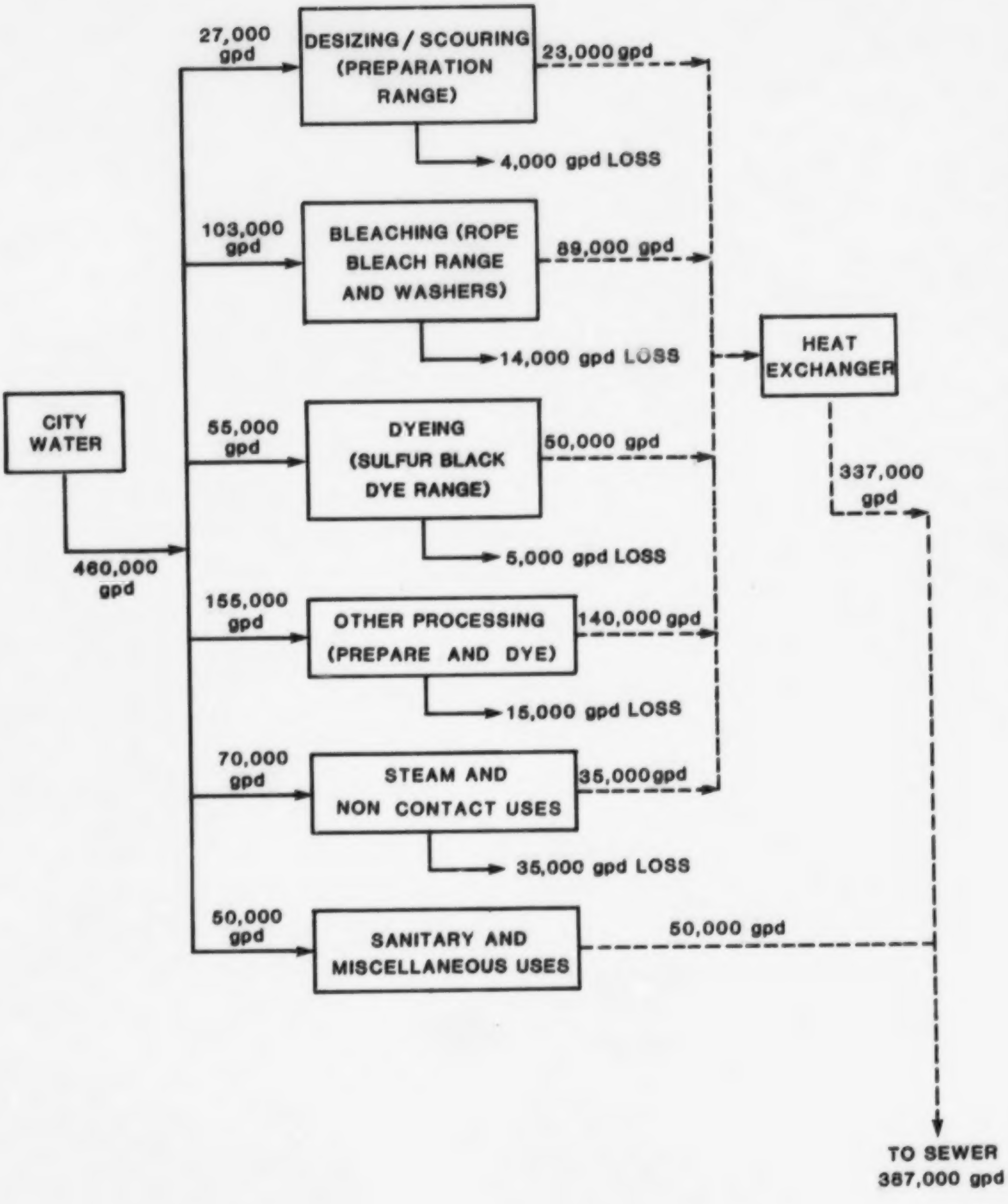

CITY WATER
460,000 gpd
27,000 gpd
DESIZING / SCOURING (PREPARATION RANGE)
23,000 gpd
4,000 gpd LOSS
103,000 gpd
BLEACHING (ROPE BLEACH RANGE AND WASHERS)
89,000 gpd
14,000 gpd LOSS
55,000 gpd
DYEING (SULFUR BLACK DYE RANGE)
50,000 gpd
5,000 gpd LOSS
155,000 gpd
OTHER PROCESSING (PREPARE AND DYE)
140,000 gpd
15,000 gpd LOSS
70,000 gpd
STEAM AND NON CONTACT USES
35,000 gpd
35,000 gpd LOSS
50,000 gpd
SANITARY AND MISCELLANEOUS USES
50,000 gpd
HEAT EXCHANGER
337,000 gpd
TO SEWER 387,000 gpd

FIGURE I -2 WATER USE AND WASTEWATER DISCHARGE

TABLE I-1
WATER USE

Description	Production yd/dy	Production lb/dy	Existing Flow gpd	Existing Ratio gal/lb
Dye Range	36,944	10,154		
Water Seal	36,944	10,154	8,000	0.8
Wash Boxes	36,944	10,154	47,000	4.6
Total	36,944	10,154	55,000	5.4
Desize Range	75,400	21,514		
1st Rinse Box	75,400	21,514	3,300	0.15
2nd Rinse Box	75,400	21,514	3,300	0.15
Total, 8 rinses	75,400	21,514	26,400	1.2
Rope Bleachery	64,000	17,800		
1st & 2nd washers	64,000	17,800	47,000	2.6
3rd & 4th washers	64,000	17,800	56,000	3.2
Total	64,000	17,800	103,000	5.8

Based on mill production and measured discharge rates during field investigation.

TABLE I-2

WATER QUALITY FOR INCOMING WATER

Parameter	Concentration (mg/l)
Alkalinity, as $CaCO_3$	18
Chloride	6.4
TS	56
Ca	4.6
Mg	1.5
Ni	0.1
Na	4.9

Source: Water sample collected on March 24, 1982.

The mill recovers energy from hot wastewater discharges through a heat exchanger before final discharge. Wastewater samples were collected from the sulfur black dye range, desize range, and rope bleachery. The sampling results for conventional and nonconventional textile pollutants are presented in Table I-3 and discussed further in subsequent sections. Table I-4, which presents a summary of pollutant loadings, indicates that about 70 percent of the COD discharged from Mill W-8 originates from the rope bleachery, desize range, and sulfur black dye range. The bleachery has the highest individual discharges of BOD, COD, and TSS. Table I-5 presents the results for all parameters measured in the final effluent.

Other wastewater constituents that affect recycle are discussed below under the appropriate recycle/reuse technologies.

EVALUATION OF RECYCLE AND REUSE TECHNOLOGIES

Recycle and reuse technologies were evaluated for three wastewater streams; rope bleachery, desizing, and sulfur black dyeing. These waste streams were selected for study because they were either large contributors of flow, BOD, and TSS, or there was potential for recovery of chemicals such as size and dye.

Table I-6 lists the recycle and reuse technologies evaluated for Mill W-8. These are discussed in detail in the following sections.

TABLE I-3

WASTEWATER CHARACTERISTICS

		Concentrations (mg/l)				
Wastewater Source	Date	BOD	COD	TSS	Phenolics	pH(S.U.)
Rope Bleachery						
Washers 1 & 2	3/22/82	5,100	11,300	1,700	0.008	11.0
Washers 1 & 2	3/23/82	3,000	24,100	2,900	0.290	9.3
Washers 3 & 4	3/24/82	540	750	60	0.014	9.4
Desize Range						
Rinse 2	3/22/82	7,500	50,000	7,700	0.130	7.0
Rinse 2	3/23/82	6,100	48,000	3,850	1.100	9.7
Rinse 1	3/24/82	13,000	20,300	4,100	1.100	9.1
Sulfur Black Dye Range						
Water Seal	3/22/82	5,400	2,300	440	0.052	6.7
Water Seal	3/23/82	4,800	2,300	140	0.002	11.1
Rinse Box 1	3/24/82	4,900	7,700	190	0.003	11.5
Final Effluent	3/22/82	4,900	6,400	1,900	0.061	10.0
	3/23/82	4,000	6,400	800	0.085	10.0
	3/24/82	1,200	2,800	490	0.200	9.0

TABLE I-4
POLLUTANT LOADINGS

Source	Flow		BOD		COD		TSS	
	gpd	% total	lb/day	% total	lb/day	% total	lb/day	% total
Rope Bleachery	89,000	23	1,600	15	6,200	36	800	24
Desize Range	23,000	6	1,250	11	4,300	25	800	24
Sulfur Black Dye Range	50,000	13	1,210	11	1,540	9	50	2
Other*	225,000	58	6,940	63	4,960	30	1,650	50
Final Effluent	387,000	100	11,000	100	17,000	100	3,300	100

*Includes several continuous ranges used for dyeing or preparation, utilities, noncontact water, sanitary and miscellaneous uses.

Note that while 70 percent of the mill effluent COD is represented in the wastewater from the bleachery, desize range and sulfur black dye range, only 37 percent of the BOD and 50 percent of the TSS is represented in these sources. This is in part due to precipitation reactions and dilution of BOD inhibitory substances as the various waste streams are combined, diluted, cooled, and undergo pH and other changes.

TABLE I-5
FINAL EFFLUENT

Parameter	Concentration (mg/l)		
	3/22/82	3/23/82	3/24/82
Total BOD_5	4,900	4,000	1,200
COD	6,400	6,400	2,800
Alkalinity as $CaCO_3$	130	170	270
Chloride	120	440	180
Oil & grease	79	--	--
Phenolics	.061	.085	.200
TS	5,800	6,400	3,500
TDS	4,900	6,300	5,400
TSS	1,900	800	490
Turbidity, NTU	300	350	120
Ca	6.6	13	6.1
Cu	0.15	0.12	--
Mg	13	12	9.4
Ni	0.1	0.1	0.1
Na	470	600	340
pH, field measure, units	10	10	9
Color (ADMI)	8,200	7,300	11,500
Temperature, °F	95	--	104

TABLE I-6
RECYCLE AND REUSE TECHNOLOGIES EVALUATED FOR MILL W-8

Source	Objective	Technique
Rope Bleachery	Reduce water use	Countercurrent rinsing
Desizing range	Reduce water use	Countercurrent rinsing
	Reduce discharge of TSS & BOD, recovery of starch for backfilling, and recovery of hot water	Membrane Separation
Sulfur black dye range	Reduce water use	Countercurrent rinsing
	Reduce discharge of TSS, BOD; recovery of dyeing chemicals; and recovery of hot water	Hyperfiltration

SECTION II
ROPE BLEACHERY

DESCRIPTION OF MANUFACTURING PROCESS

The rope bleachery at Mill W-8 is illustrated in schematic form in Figure II-1. The fabric is saturated with caustic and hydrogen peroxide in the first stage of the operation. After storage for a specified time in detention bins, the fabric passes through three or four rope washers. During the field investigation, about 18,000 lb/day of fabric were processed on the range.

Water Use and Wastewater Characteristics

Total water use averaged about 103,000 gpd at the washers during the investigation, which yields a water use rate of 5.7 gallons of water per pound of fabric. The water use consisted of 28,000 gpd on Washer 1, 19,000 gpd on Washer 2, 37,000 gpd on Washer 3, and 19,000 gpd on Washer 4. An estimated 15 percent of the water used is lost through evaporation or retained in the fabric. Wastewater samples from the rope bleachery were collected and analyzed, and the results are shown in Table II-1. The results indicate that the major portion of contaminants are removed in the first two washers. Therefore, the potential exists for countercurrent rinsing from Washers 3 and 4 to Washers 1 and 2.

EVALUATION OF THE POTENTIAL FOR REUSE

Technical Feasibility

Mill W-8 has the capability to use countercurrent rinsing on the washers but does so only occasionally. No extensive data have been gathered by the mill on the effects of water reduction and full countercurrent rinsing, though mill personnel have commented that they feel fabric quality will suffer. Several studies by Groves, Buckley, and Turnbull* indicated that washer performance levels off beyond a

*Closed Looped Recycle Systems for Textile Effluents," JWPCF, March 1979, p. 499.

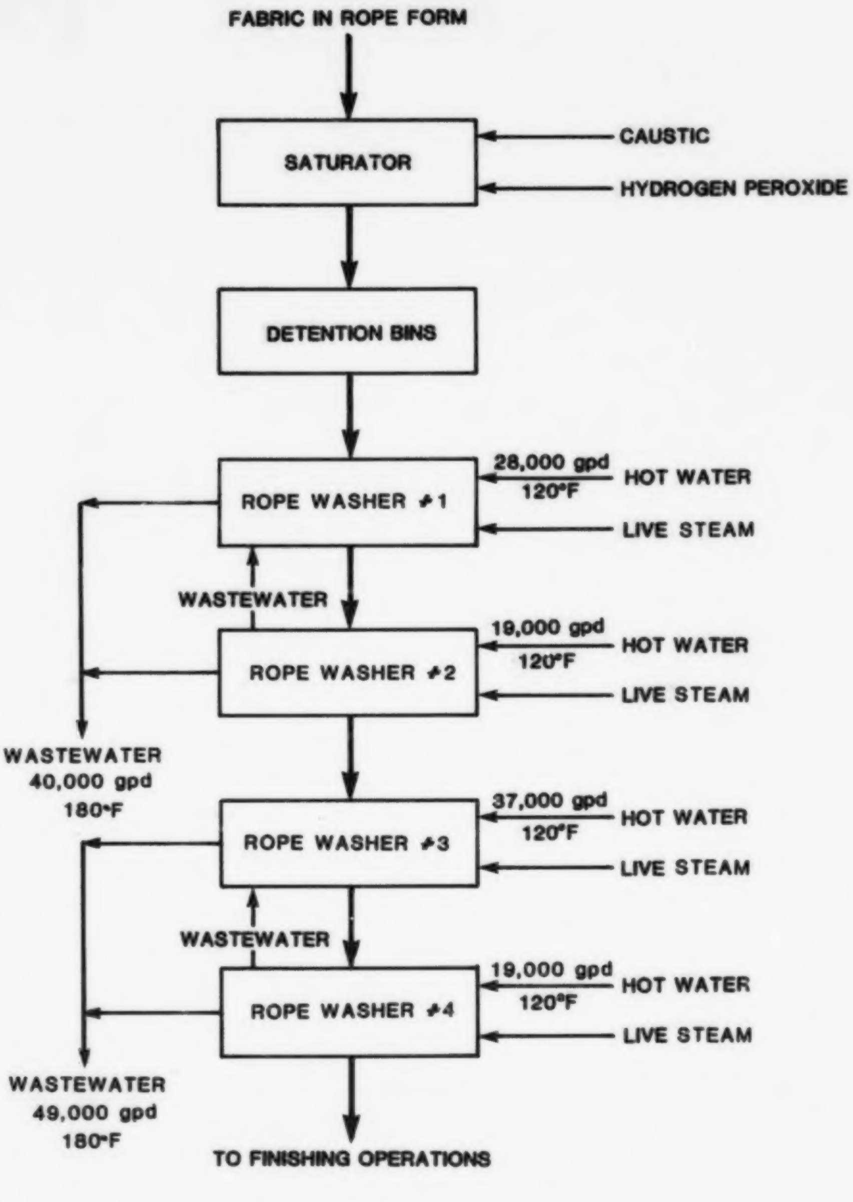

FABRIC IN ROPE FORM
SATURATOR
CAUSTIC
HYDROGEN PEROXIDE
DETENTION BINS
ROPE WASHER #1
28,000 gpd
120°F
HOT WATER
LIVE STEAM
WASTEWATER
ROPE WASHER #2
19,000 gpd
120°F
HOT WATER
LIVE STEAM
WASTEWATER
40,000 gpd
180°F
ROPE WASHER #3
37,000 gpd
120°F
HOT WATER
LIVE STEAM
WASTEWATER
ROPE WASHER #4
19,000 gpd
120°F
HOT WATER
LIVE STEAM
WASTEWATER
49,000 gpd
180°F
TO FINISHING OPERATIONS

FIGURE II-1 SCHEMATIC OF ROPE BLEACHERY

TABLE II-1
WASTEWATER CHARACTERIZATION
ROPE BLEACHERY

		Concentration (mg/l)		
	Washer:	1 & 2	1 & 2	3 & 4
Parameter	Date:	3/22/82	3/23/83	3/23/82
Total BOD_5		5,100	3,000	540
Soluble BOD_5		3,800	3,000	640
COD		11,300	24,100	750
Alkalinity as $CaCO_3$		1,500	790	120
Chloride		97	63	140
Oil & grease		--	100	--
Phenolics		.008	.290	.014
TS		11,500	19,000	1,100
TDS		11,000	5,900	890
TSS		1,700	2,900	60
Turbidity, NTU		1,000	2,200	--
Ca		4.2	3.8	3.6
Cu		--	--	4.6
Mg		4.8	3.0	--
Ni		--	0.16	0.1
Na		980	730	180
pH, field measure, units		11	9.3	9.4
Color (ADMI)		1,210	4,300	--
Temperature °F		180	180	170

water consumption of 1 gallon per lb of fabric. They conclude that full countercurrent flow systems should operate efficiently at water use levels as low as 1 gallon per pound of fabric. These studies and the wastewater characteristics suggest that more extensive counterflow washing has potential for success at this mill. The actual water use in such a system needed to achieve desired fabric quality must be determined by the mill through actual testing.

Economic Feasibility

Savings in water and energy can be realized by the implementation of countercurrent rinsing, and no capital or additional O&M costs are expected, therefore yielding an immediate payback.

Two levels of countercurrent rinsing were considered and are presented in Table II-2:

1. Countercurrent flow from Washers 3 and 4 to Washers 1 and 2.
2. Full countercurrent flow and water use reduction to 1 gallon/lb fabric.

As shown in Table II-2, substantial cost and water savings can be realized through countercurrent washing.

ENVIRONMENTAL EFFECTS

The pollutant load is not expected to be reduced by countercurrent rinsing, because the same removal of impurities is expected. Water and energy requirements will be reduced as stated above.

CONCLUSIONS

- Reuse of rope washer wastewater through countercurrent rinsing appears to be technically and economically feasible.
- Testing must be performed to determine actual water and energy savings achievable without sacrificing fabric quality.

TABLE II-2

ECONOMIC ANALYSIS OF COUNTERCURRENT WASHING

	Existing	Case 1	Case 2
Fabric Bleached, lb/day	18,000	18,000	18,000
Water Flow, gpd			
Washer 1	28,000	0	0
Washer 2	19,000	0	0
Washer 3	37,000	37,000	0
Washer 4	19,000	19,000	18,000
Total	103,000	56,000	18,000
Water Use, gal/lb	5.7	3.1	1.0
Water Savings, gpd	0	47,000	85,000
$/yr	0	5,400	9,700
Energy Savings, $/yr	0	18,300	33,000
Total Savings, $/yr	0	24,700	42,700

Notes:

1. Water savings based on 260 day/year operation and water/sewer costs of $0.44 per 1000 gallons

2. Energy savings based on 260 day/year operation, energy costs of $3/million BTU, and heating the washwater from 120°F to 180°F

SECTION III

SIZE RECOVERY BY ULTRAFILTRATION/HYPERFILTRATION

DESCRIPTION OF MANUFACTURING PROCESS

Starch-sized fabric is desized on an open-width range as shown in Figure III-1. The fabric is saturated with an enzyme solution, retained in a J-box for about two minutes, and rinsed thoroughly with hot water. The rinsing occurs in a series of eight open-width rinse boxes. The temperature of the rinse boxes varies from 120°F to 200°F. Make-up water for this rinse system is preheated to 120°F through the plant heat exchanger system. Live steam is added to each rinse box as required. The range is capable of countercurrent rinsing and this is sometimes used. During the field investigation, about 22,000 lb/day of fabric were processed on the range.

Water Use and Wastewater Characteristics

As shown in Figure III-1, total water use during this study averaged 27,000 gpd on this range, resulting in a water use rate of 1.2 gallons per pound of fabric. About 15 percent of the water is lost through evaporation or retained in the fabric after desizing.

Wastewater samples from the first two rinse boxes on the desize range were collected and analyzed, and the results are shown in Table III-1. The results indicate a concentrated organic wastewater due to the removal of starch and, occasionally, various synthetic sizes.

EVALUATION OF THE POTENTIAL FOR REUSE

Technical Feasibility - Countercurrent Rinsing

The mill has nearly optimized the control of water use at the desize range, judging from the water use rate of 1.2 gallons per pound of fabric. Countercurrent rinsing potentially could reduce the quantity of water required at the desize range even further, from 27,000 gpd to 22,000 gpd. Facilities for countercurrent rinsing are already in place at the desizing range. However, it is not now used because mill personnel believe that once-through rinsing produces a higher quality

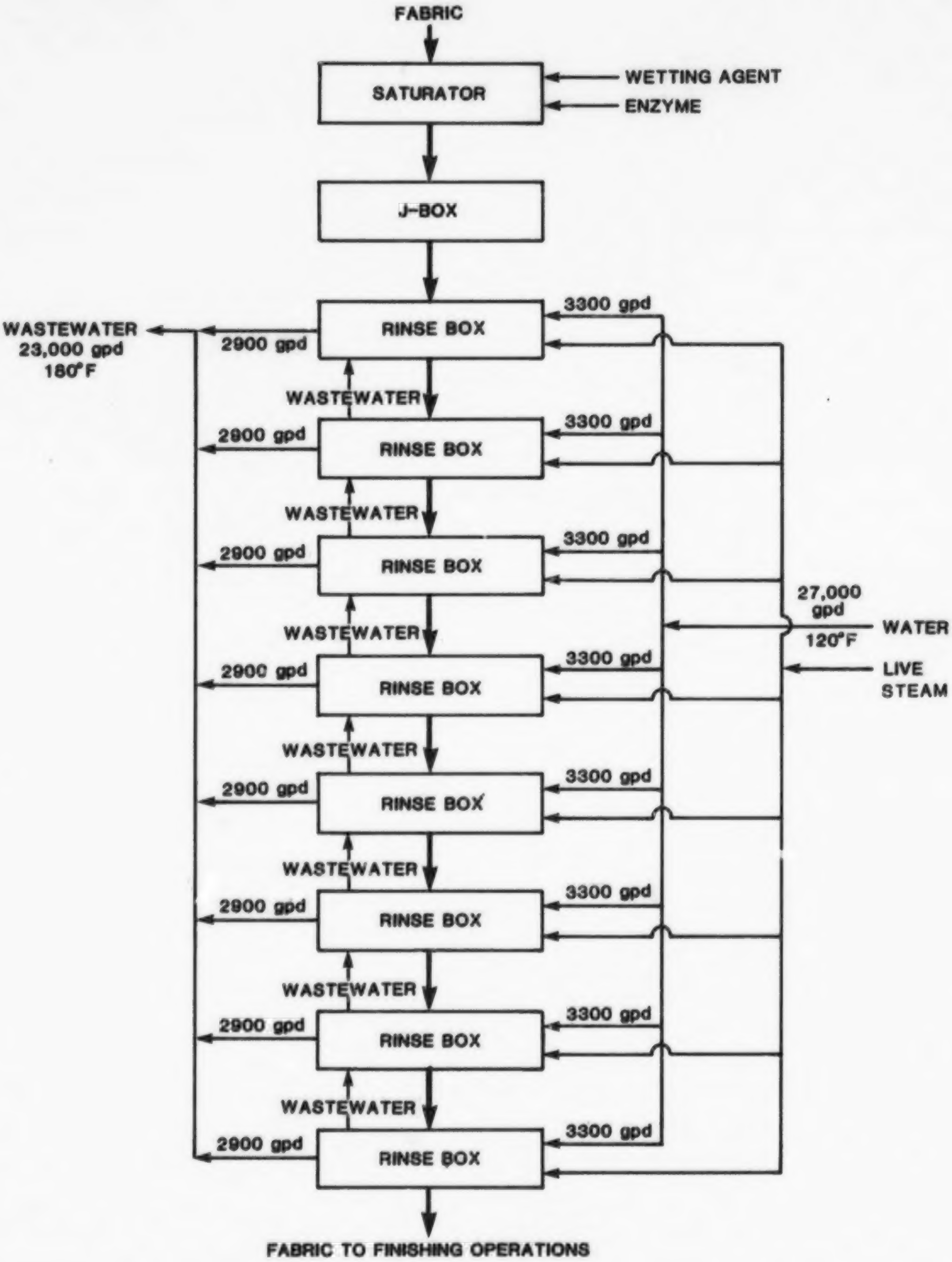

FABRIC
SATURATOR
WETTING AGENT
ENZYME
J-BOX
RINSE BOX
3300 gpd
2900 gpd
WASTEWATER
23,000 gpd
180°F
WASTEWATER
27,000
gpd
120°F
WATER
LIVE
STEAM
FABRIC TO FINISHING OPERATIONS

FIGURE III-1 SCHEMATIC OF OPEN WIDTH DESIZING OPERATION

TABLE III-1
WASTEWATER CHARACTERIZATION
DESIZE RANGE

	Concentration (mg/l)		
Parameter	Rinse 1 3/24/82	Rinse 2 3/22/82	Rinse 2 3/23/82
Total BOD_5	13,000	7,500	6,100
Soluble BOD_5	--	7,400	5,100
COD	20,300	50,000	48,000
Alkalinity as $CaCO_3$	--	210	710
Chloride	--	730	53
Oil & grease	--	880	230
Phenolics	1.1	.130	1.1
TS	28,000	33,600	26,000
TDS	22,000	21,000	13,600
TSS	4,100	7,700	3,850
Turbidity, NTU	2,100	2,400	5,200
Ca	9.4	13	4.5
Mg	15	14	10
Ni	0.12	0.14	0.10
Na	680	540	600
pH, field measure, units	9.1	7.0	9.7
Color (ADMI)	4,950	6,400	2,000
Temperature °F	125	180	180

product, though they have not confirmed this with any extensive testing. Further tests are needed to determine if fabric quality will be adversely affected by countercurrent rinsing.

Technical Feasibility - Size Recovery

Although ultrafiltration has been successfully used to recover synthetic size compounds, starch recovery has not been demonstrated. Starch desizing is frequently done with enzymes that break down the starch into smaller products of hydrolysis. The degree of hydrolysis that occurs is a function of time. Therefore, if the desize wastewater can be treated rapidly and the hydrolysis reaction stopped, recovery of a usable by-product from the desize wastewater may be possible. Alternately, desizing can be done with hot water and caustic rather than with enzymes in an attempt to avoid complete degradation of the starch. In any case, some degradation of starch occurs during the desizing process, and additional bench-scale or pilot-scale research is needed to determine if a usable by-product can actually be recovered by membrane filtration at Mill W-8. Bench scale tests performed for this study have indicated that the starch by-products are only partially concentrated by membrane filtration. This means that the hydrolysis reaction has progressed far, resulting in smaller compounds that are not efficiently recovered by hyperfiltration. A complete description and results of the membrane bench tests performed in this study is provided in Appendix A.

An attempt was made by mill personnel to reuse the hyperfiltration membrane concentrate (containing the recovered starch by-products) in the mill's backfilling operation. A sample was used as makeup for the starch-talc solution applied as a hand builder. The results were not satisfactory. It has been speculated by mill personnel that the concentrate stream contained little usable starch due to the hydrolysis reaction during desizing.

A further consequence of the poor recovery noted in the tests is that the hyperfiltration membrane permeate contains high concentrations of pollutants. This will seriously hinder its ability to be recycled to the desize washers.

Economic Feasibility - Countercurrent Rinsing

Cost savings from countercurrent rinsing result from water and energy savings. As stated earlier, however, this range has nearly optimized its water use rate so that the amount of water use that could be saved by using countercurrent rinsing is small. The projected water and energy savings are expected to be less than $1,000 per year. No capital costs are expected for implementation of countercurrent rinsing since the facilities are currently in place.

Economic Feasibility - Size Recovery

Although the technical feasibility of starch recovery remained unproven as a result of the bench-scale tests discussed above, it was decided that the economics of starch recovery should be investigated. If the economics were promising, then further research into the technical feasibility of starch by-product recovery might be justified.

Cost savings from treatment/recycle of the desize wastewater can result from water use savings, sewer surcharge savings, size recovery, and energy savings. Operating costs result from the operation of the membrane separation system. The basis for costs and savings estimates is as follows:

Water = $0.44/1,000 gallons
TSS surcharge = $47/1,000 lb TSS discharged
BOD surcharge = $60/1,000 lb BOD discharged
Starch = $14.81/100 lb
Steam = $3.57/1,000 lb ($3 per million Btu)

Desizing operation is conducted 260 days per year.

Starch is applied at 1 percent of fabric weight on 65 percent of production; assume less than half is available for recovery, which is optimistic, based on the preliminary tests discussed under technical feasibility.

Capital and operating costs are estimated from literature data collected during this study.

Since no full scale systems of this type are operating on starch desizing wastes, these capital and operating costs are considered to be order-of-magnitude estimates only.

A summary of the results of the economic analysis is provided in Table III-2. Even with 50 percent starch by-product recovery, no payback is expected for this recycle technology.

ENVIRONMENTAL EFFECTS

Size recovery and reuse normally results in signficant reductions to the BOD and TSS from a finishing mill. However, since starch reuse has not been shown to be practical, no environmental benefits are seen resulting from the use of membrane processes to treat desizing wastewater at this mill.

CONCLUSIONS

- Recovery of by-products by membrane separation processes remains completely unproven; extensive research and testing are necessary to prove technical feasibility.
- The value of recovered starch, even if the technology were developed, is not enough to justify the costs of recovery.
- Environmental benefits would be minimal at this mill.

TABLE III-2
SUMMARY OF ECONOMIC ANALYSIS
SIZE RECOVERY BY MEMBRANE SEPARATION

Capital Cost (22,000 gpd system)		$409,000
Annual Savings		
Water	(21,000 gpd)	$ 2,300
Starch	(500 lb/day)	$ 19,000
TSS	(55 lb/day)	$ 800
BOD	(550 lb/day)	$ 8,600
Energy	(5,700 lb steam/day)	$ 5,200
Total Savings		$ 36,000
Annual Operating Costs		$ 57,000

Net Annual Cost = $21,000/yr. Therefore, no payback is expected.

SECTION IV

SULFUR BLACK DYEING - DYE RECOVERY BY HYPERFILTRATION

DESCRIPTION OF MANUFACTURING PROCESS

Figure IV-1 is a schematic of the sulfur black dye range. Fabric passes through a dye pad containing two gallons of the stock dye solution per ten gallons of dye pad solution. Approximately 2,900 pounds of stock dye are used each day. The dyed fabric passes through a steamer, water seal, and nip. Next are six rinse boxes connected for countercurrent rinsing. The temperature of the water from the water seal and the first six rinse boxes is about 140°F; the pH is typically about 11, resulting from the caustic nature of the dye solution. Following that is a brine bath to oxidize the sulfur dye, and three rinse boxes connected for countercurrent rinsing. During the field investigation, about 10,000 pounds of fabric per day were processed on this range. However, this production varies with market demand.

Water Use and Wastewater Characteristics

As indicated in Figure IV-1, the total water use at the sulfur black dye range is about 55,000 gpd, resulting in a water use rate of 5.5 gallons per pound of fabric. About 10 to 15 percent of the water is lost through evaporation or retained in the fabric after the wet process.

Wastewater samples from the water seal and first rinse box of the dye range were collected and analyzed, and the results are shown in Table IV-1. These locations are expected to contain most of the economically recoverable dye. The results indicate a highly colored wastewater with a dilution factor of about 130 to 1 of the stock dye solution. This dilution factor is used to calculate the amount of recoverable stock dye solution in the wastewater for the economic analysis. Discharge of BOD, COD, and TSS from the dye range is a fairly minor portion of the total mill effluent, as indicated in Table I-4.

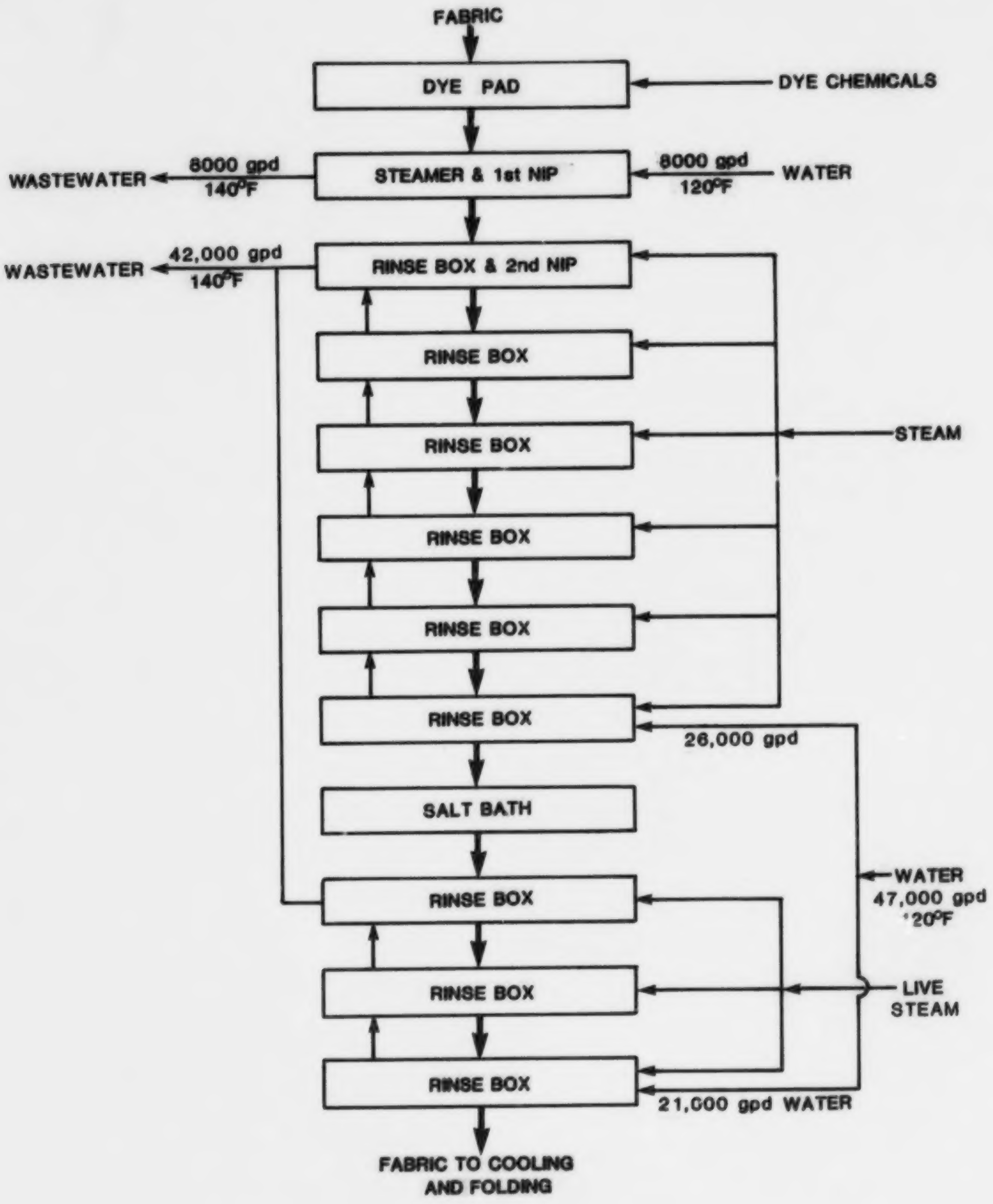

FABRIC
DYE PAD
DYE CHEMICALS
WASTEWATER
8000 gpd
140°F
STEAMER & 1st NIP
8000 gpd
120°F
WATER
WASTEWATER
42,000 gpd
140°F
RINSE BOX & 2nd NIP
RINSE BOX
RINSE BOX
STEAM
RINSE BOX
RINSE BOX
RINSE BOX
26,000 gpd
SALT BATH
RINSE BOX
WATER
47,000 gpd
120°F
RINSE BOX
LIVE
STEAM
RINSE BOX
21,000 gpd WATER
FABRIC TO COOLING
AND FOLDING

FIGURE IV - 1 SCHEMATIC OF SULFUR-BLACK DYE RANGE

TABLE IV-1
WASTEWATER CHARACTERIZATION
SULFUR BLACK DYE RANGE

Parameter	Concentration (mg/l) Water Seal 3/22/82	 Water Seal 3/23/82	 1st Rinse 3/23/82
Total BOD_5	5,400	4,800	4,900
COD	2,300	2,300	7,700
Alkalinity as $CaCO_3$	1,800	1,500	1,600
Chloride	2,100	3,900	3,100
MBAS	110	190	200
Oil & grease	76	--	--
Phenolics	.052	.002	.003
TS	12,000	12,000	14,800
TDS	14,000	10,000	14,600
TSS	440	140	190
Turbidity, NTU	1,000	--	--
Ca	13	16	12
Cu	0.1	0.1	0.1
Mg	2.8	2.1	1.9
Ni	0.16	0.15	0.20
Na	2,700	2,300	3,200
Color (ADMI)	244,000	178,000	142,000
Dilution factor of stock dye solution	123	133	143
Temperature °F	140	140	--

PROPOSED MODIFICATION OF THE DYE RANGE OPERATION FOR REUSE

Although countercurrent rinsing is already in use, it may be possible to further reduce the amount of water used in the first six rinse boxes from about 26,000 gpd to about 10,000 gpd to achieve an optimum water use rate of 1 gallon per pound of fabric in the rinsing stage. This would also minimize the water flow to be treated for dyestuff recovery. A similar water use rate has been successfully achieved in the full-scale hyperfiltration system operating at LaFrance Industries.

The waste rinse water from the water seal and the first six wash boxes contains valuable dye. Hyperfiltration is applicable for separating the wastewater into a concentrated dye solution and a permeate suitable for recycle as a rinsewater at the dye range. A blowdown from both the concentrate and the permeate is necessary to prevent the buildup of impurities.

TECHNICAL FEASIBILITY

One full-scale application of hyperfiltration has recently been installed at LaFrance Industries. Preliminary reports indicate that this hollow-tube system is economical at that mill. Zirconium oxide polyacrylate hollow-tube systems are capable of treating wastewater at high temperatures and high pH as found at textile mills. A complete discussion of the applicability of this technology is provided in Volume 1. The technology has good potential at this range because long runs of a single dye type are generally processed, enabling a more simplified recovery and reuse process for the dyes. Pilot-scale and full-scale recovery systems are in operation with indigo dyeing wastewater, a very similar application.

Hyperfiltration system design parameters include flux rates, temperature, and pressure. The values for these parameters are usually determined by pilot tests. Typical values reported in the literature are shown in Table IV-2.

TABLE IV-2
TYPICAL HYPERFILTRATION DESIGN PARAMETERS

Type of Membrane	Flux		Pressure	
	gal/sq ft-d	cu m/sq m-d	psig	k Pa
Spiral-wound poly(ether)amid	8	0.3	1,000	6,900
Spiral-wound cellulose-acetate	5	0.2	1,000	6,900
Hollow-tube Zirconium oxide polyacrylate	30	1.2	1,000	6,900

Source: Literature from equipment vendors.

ECONOMIC FEASIBILITY

Water use reduction by optimizing the rinsing operation could amount to almost 16,000 gpd, which would save about $2,000 per year. Energy savings of about 2.6 million Btu/day would result in cost savings of about $2,000 per year. Total savings of $4,000 per year are possible, though the actual water use reduction that is possible needs to be thoroughly tested to determine effects on fabric quality. No capital or operating costs are expected since the range already has the capability for counterflow rinsing.

Cost savings from treatment/recycle of the remaining 18,000 gpd dye wastewater from the water seal and first six rinse boxes can result from water use savings, sewer surcharge savings, dye recovery, and energy savings. Operating costs result from the operation of the hyperfiltration system. The basis for costs and savings estimates for dye recovery by hyperfiltration is as follows:

Water = $0.44/1,000 gallons
TSS surcharge = $47/1,000 lb TSS discharged
BOD surcharge = $60/1,000 lb BOD discharged
Sulfur Black Dye = $0.45/lb stock dye solution
Steam = $3.57/1,000 lb ($3 per million Btu)

Dyeing operation is conducted 260 days per year.

The stock dye solution found in the wastewater showed a dilution factor of 123-143 to 1, depending on the sample location. This results in a recoverable dye quantity of about 1,700 lb/day. However, the mill has stated that only 2,900 lb/day are applied and feel that the 1,700 lb/day amount may be excessive.

Capital and operating costs for the dye recovery system are from cost curves developed in Volume 1. A summary of the results of the economic analysis is provided in Table IV-3. The payback period of 2 years is very sensitive to the dye savings actually achieved. For example, if the recoverable dye quantity is only 1,000 lb/day, the payback period increases to 4 years.

TABLE IV-3

SUMMARY OF ECONOMIC ANALYSIS

DYE RECOVERY

Capital Cost (18,000 gpd system)	$364,000
Annual Savings	
Water (26,000 gpd)*	$ 3,000
Sulfur Black Dye (1,700 lb/day)	$199,000
TSS (Savings not expected)	-0-
BOD, (960 lb/day)	$ 15,000
Energy (4 million Btu/day)	$ 3,100
Annual Costs	$ 50,000
Net Annual Savings	$170,000
Payback period	$364,000/$170,000 per year = 2.1 years

* Includes savings from countercurrent rinse water use reduction

ENVIRONMENTAL EFFECTS

Reduction in BOD and color is expected as a result of installation of a hyperfiltration system. However, since the sulfur black dye range contributes only about 11 percent of the total mill effluent BOD, the effect will not be significant. Color reductions in the wastewater from this range will be substantial.

CONCLUSIONS

- Recovery of sulfur black dye by hyperfiltration appears to be technically and economically feasible, but some pilot testing is necessary to confirm this and refine the design criteria for the unit.
- The actual value of recovered dye must be investigated thoroughly to confirm the economic analysis presented in this report.
- Environmental benefits of dye recovery are expected to be small at this mill, since continuous sulfur black dyeing represents only a small portion of the mill's total production.

APPENDIX A

Screening Test

Starch Desize of Solids

Project #92

for

Sverdrup & Parcel and Associates, Inc.

April 6, 1982

CARRE, INC.
CONSERVATION AND RESOURCE RECOVERY ENGINEERING
109 Debra Street, P. O. Box 1555, Seneca, South Carolina 29678
CONSULTING, DESIGN, AND SPECIALTY EQUIPMENT FOR ENERGY, CHEMICALS, AND WATER RECYCLE

TEST FOR SVERDRUP AND PARCEL

S & P is under contract with EPA to evaluate recycle/reuse for indirect dischargers in the textile industry. Hyperfiltration (HF) and ultrafiltration (UF) are technologies being considered. Screening tests of UF and HF have been carried out on several process effluents under previous research grant programs. The current screening test is of a starch desize liquid that has not been specifically evaluated. The starch in the sample has been enzyme treated in the process. The sample was preserved with 1 pint of formaldehyde in a 55 gallon drum sample.

Experience with ZOPA membranes in the treatment of food stuffs suggests the sugar rejection will be low. However, some streams have exhibited adequate 'self-rejecting' characteristics. This present test is undertaken as a screening test. New HF membranes under development for food processing may be evaluated later.

Objective: The objective of this screening test is to generate samples of permeate and concentrate using both UF and HF membrane processing a starch desizing solution which has been treated with enzymes. The BOD and COD of the permeate will be evaluated, by S & P. A sample of concentrate was returned to Mill W-8 for reuse evaluation.

Relationship to Other Tasks: The results of the present test will be used to evaluate technologies and applications for the on-site pilot testing portion of the program. Since the the enzyme action converts the starch to sugar, subsequent screening tests may be required, also.

Equipment: A small skid-mounted pumping unit, schematically shown in Figure 1, with a conical bottom feed tank, was used. Module No. 540, (1/2-inch, porous S. S. tubing); with HF membrane was used. A U. F. membrane module (5/8-inch, porous S. S. tubing), N-37; was used. The two membrane modules were connected in series and evaluated simultaneously.

EXPERIMENTAL:

Sampling:

As requested, samples were collected in brown glass bottles supplied by S & P. The samples taken and the results of CARRE's analysis are listed in Table 1. The samples were stored in a refrigerator at 36° overnight

P = PRESSURE GAUGE
HBS = HIGH PRESSURE SWITCH
LPS = LOW PRESSURE SWITCH

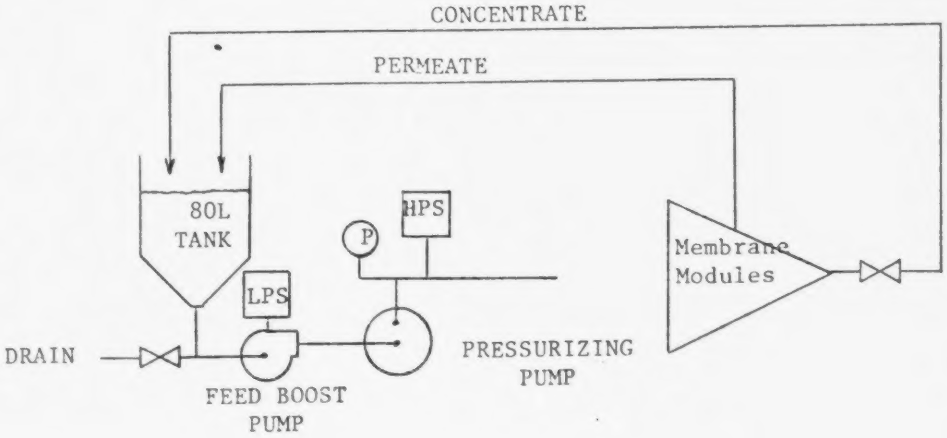

CONCENTRATE
PERMEATE
80L TANK
HPS
P
LPS
Membrane Modules
DRAIN
FEED BOOST PUMP
PRESSURIZING PUMP

Figure 1

TOLERANCES (EXCEPT AS NOTED)	REVISIONS		
	NO.	DATE	BY
DECIMAL ±	1		
	2		
FRACTIONAL ±	3		
	4		
ANGULAR ±	5		

TYPE D UNIT SCHEMATIC

CARRE INC.
SENECA, SC. 29678

DRAWN BY RDH	SCALE NONE	MATERIAL
CHK'D	DATE 4-6-82	DRAWING NO.
TRACED	APP'D	

TABLE 1. RESULTS OF SAMPLE ANALYSIS FOR S & P TEST ON STARCH DESIZE SOLUTION

Sample No.	Sample Type	Recovery (%)	pH	Conductivity (μm/cm)	Rejection (%)	Total Solids (mg/ℓ)	Rejection (%)	% Sugar (as glucose)	Rejection (%)
1	Feed - As rec'd.	-	6.25	2100	-	18130	-	0.49	-
2	Permeate, UF	0	6.25	1500	33	4730	70	0.215	55
3	Permeate, HF	0	6.25	740	67	1420	91	0.098	80
4	Feed	0	6.25	2250	-	16000	-	0.482	-
5	Permeate, UF	80	6.05	3100	23	9070	81	0.45	58
6	Composite, HF	80	6.25	2700	33	4660	84*	0.191	80*
7	Concentrate	80	6.25	4000	-	48760	-	1.06	-
8	Permeate, UF	90	6.05	3300	27	13060	82	0.52	74
9	Composite, HF	90	6.25	3600	20	5360	∿85*	0.22	80*
10	Concentrate	90	6.25	4500	-	73750	-	2.01	-

* Membrane Rejection based on Eqn (1):

$$\overline{Cp}/_{Cf} = \frac{1}{R}\left\{1 - (1 - R)^{1-2}\right\} \text{-------------------------- Eqn. (1)}$$

$\overline{Cp}$ = concentration of composite permeate

Cf = concentration of feed

R = recovery

J = membrane rejection

TABLE 1A
DESIZE RANGE
BENCH TEST RESULTS FOR MEMBRANE SEPARATION

Sample Number & Type	Recovery (Percent)	Total BOD5 (mg/l)	COD (mg/l)	TS (mg/l)	TS* Rejection (Percent)	Conductivity* (um/cm)	Conductivity Rejection (Percent)	Percent* Sugar as Glucose	Sugar* Rejection (Percent)	pH* Lab (S.U.)
1. Feed as Received	--	7,600	24,000	18,000 (18,100*)	--	2,100	--	0.49	--	6.25
2. UF Permeate	0	3,500	6,100	4,700 (4,730*)	70	1,500	33	0.215	55	6.25
3. HF Permeate	0	1,600	2,300	2,300 (1,420*)	91	740	67	0.098	80	6.25
4. Feed to Membrane Filter	0	7,400	21,500	17,500 (16,000*)	--	2,250	--	0.482	--	6.25
5. UF Permeate	80	6,000	10,000	10,100 (9,070*)	81	3,100	23	0.45	58	6.05
6. HF Composite	80	2,800	5,900	4,600 (4,660*)	84	2,700	33	0.191	80	6.25
7. Concentrate	80	21,000	177,000	52,200 (48,800*)	--	4,000	--	1.06	--	6.25
8. UF Permeate	90	7,000	13,400	13,300 (13,100*)	82	3,300	27	0.52	74	6.05
9. HF Composite	90	3,100	6,200	5,700 (5,360*)	85	3,600	20	0.22	80	6.25
10. Concentrate	90	7,500	113,000	91,000 (73,800*)	--	4,500	--	2.01	--	6.25

until shipment was made by Federal Express on Tuesday, March 30, 1982. (See Attachment for sample handling and shipping procedures).

Test Procedure:

The testing began on March 29, 1982. After mixing the solution thoroughly, while in the 55 gallon barrel, an "as received" sample was collected and stored. The test unit was cleaned with mild base and acid washes and rinsed. The membrane modules were then placed in the loop and a reference salt data point recorded using a 0.01M $NaNO_3$ solution. The loop was drained. Seventy eight (78) liters of feed was placed into the loop. The system was started up and the solution recirculated at 600 psig for one hour at zero recovery. Data was collected every thirty (30) minutes. After the hour a pressure excursion from 200 to 900 psig was performed. Samples of feed and permeate were collected and stored. Collection of HF permeate in the stainless steel barrel was begun. After four (4) hours operating time (approximately 29% recovery) twenty six (26) liters of concentrate were accidentally spilled. Thirty six (36) liters of fresh feed solution was placed into the loop. Concentration continued for three (3) hours. At this time the system pressure was lowered to 500 psig and the HF permeate flow was divided sending a small portion to the permeate holding tank and the remainder to be recycled to the feed tank, thus allowing concentration to slowly continue overnight.

The following morning (March 30, 1982) all permeate was recycled and samples of permeate and concentrate were collected and stored. Concentration was then continued until eight (8) liters of concentrate remained. Permeate was recycled while a pressure excursion between 200 and 900 psig was performed. Samples of concentrate and permeate were collected and stored. System was then drained and rinsed. Reference data in the reference 0.0 $\underline{M}$ $NaNO_3$ solution was then recorded.

A small volume (approximately 50 ml) was taken from each sample prior to their shipment for total solids, sugar, conductivity, and pH measurement in the CARRE laboratory. The samples were then packed in ice and shipped to Sverdrup Technology, Tullahoma, TN. A one (1) liter samples of the concentrate was shipped to Mill W-8 for tests. Duplicate samples were collected and stored at CARRE, Inc. pending arrival of the shipped samples.

The Test Result Summary sheet for each membrane is attached. Also attached are copies of the data taken during the test.

Results

Figure 2 is a summary in time of the membranes' fluxes, conductivity rejections and operating conditions throughout the test. The H.F. and U.F. membrane conductivity rejections declined throughout the test. Total solids and glucose rejections remained near constant for the H.F. membrane and rose for the U.F. membrane as the membrane fouled. While these tests yield representative rejections, fluxes during these short term test are not representative of design values. Fluxes in the field can be either higher or lower than those seen in screening tests.

There is a very rapid accommodation of the membrane to the fluid which dropped the H.F. flux to approximately 1/3 and the U.F. flux 1/5 of its original flux with the reference salt solution. The flux remained low for the final reference salt data indicating either a tenacious fouling layer or a chemical interaction between the fluid and membrane which changed the membrane's transport properties. The decline in conductivity rejection might point to the latter phenomenon.

Figures 3 and 4 show the effects of pressure on flux and conductivity rejection for the U.F. and H.F. membrane, respectively. Both membranes show a non-linear response which is indicative of a fluid boundary layer which impedes the flux. This is expected in a starch solution.

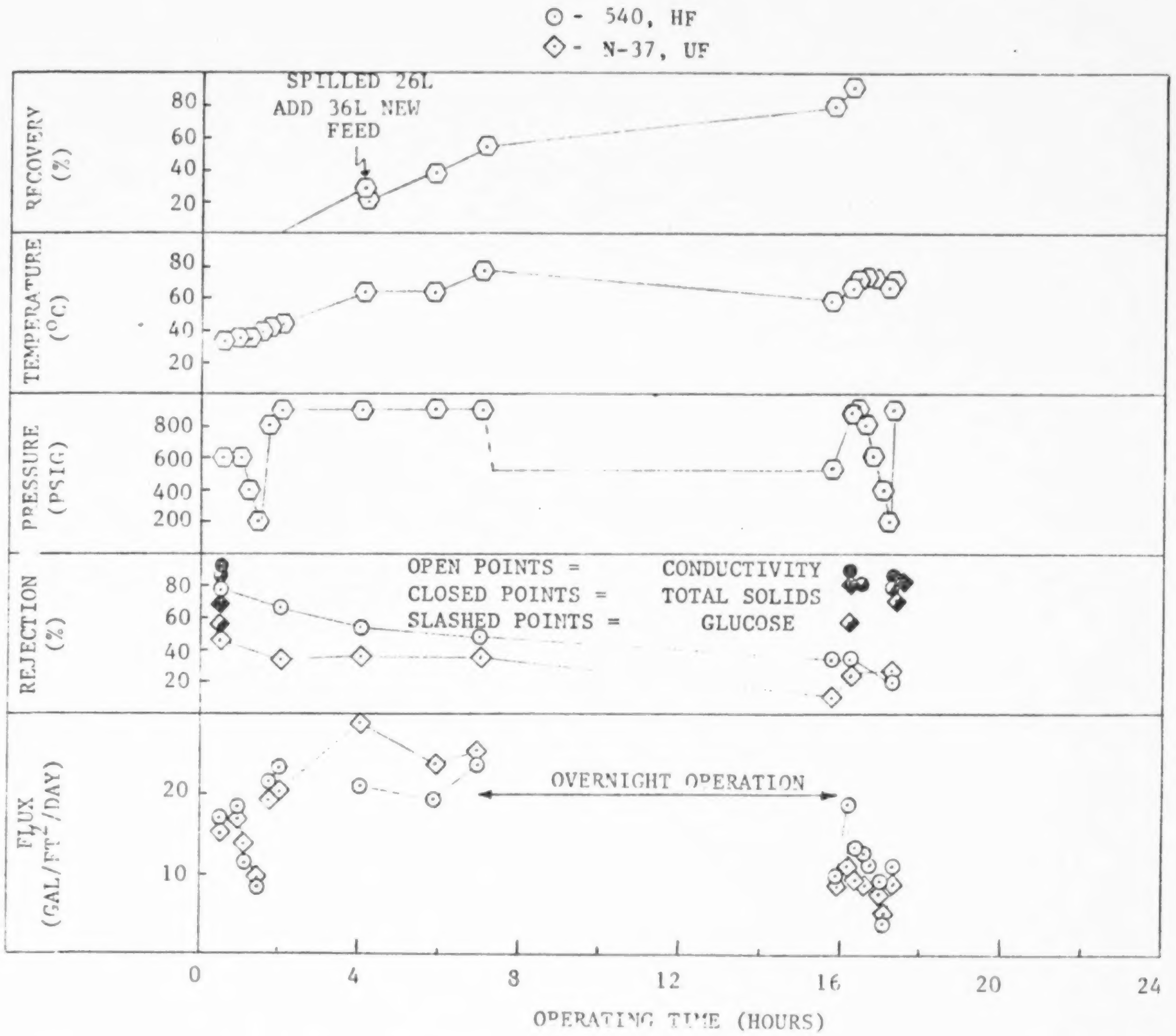


FIGURE 2. FLUX AND REJECTIONS VERSUS TIME FOR MODULE NO. 540 (HF) AND N 37 (UF) OPERATED IN A STARCH DESIZE SOLUTION AT VARIOUS OPERATING CONDITIONS

Reproduced from best available copy.

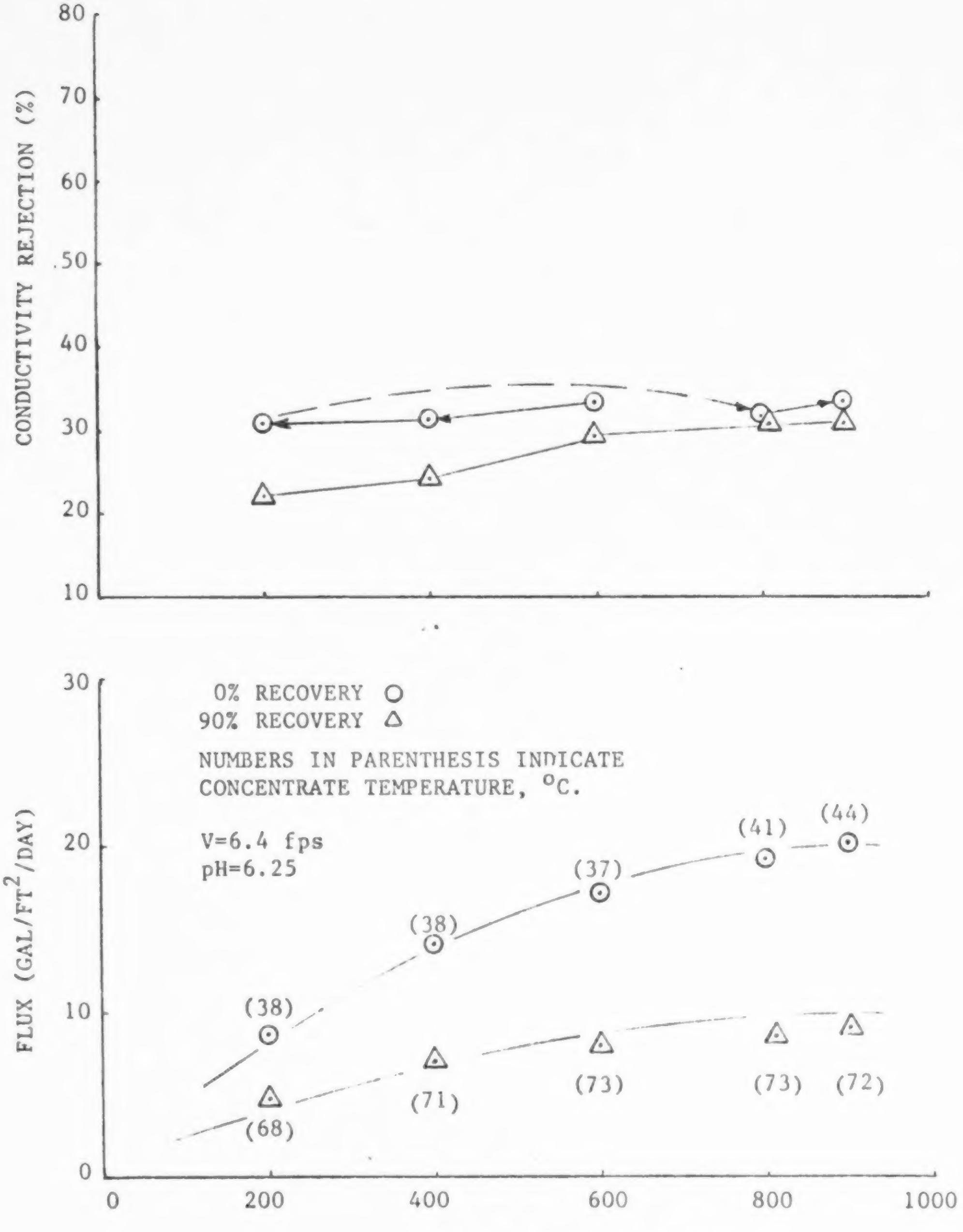


FIGURE 3. FLUX AND CONDUCTIVITY REJECTION VERSUS PRESSURE FOR MODULE NO. N 37 (UF) OPERATED IN A STARCH DESIZE SOLUTION AT ZERO AND NINETY PERCENT RECOVERY.

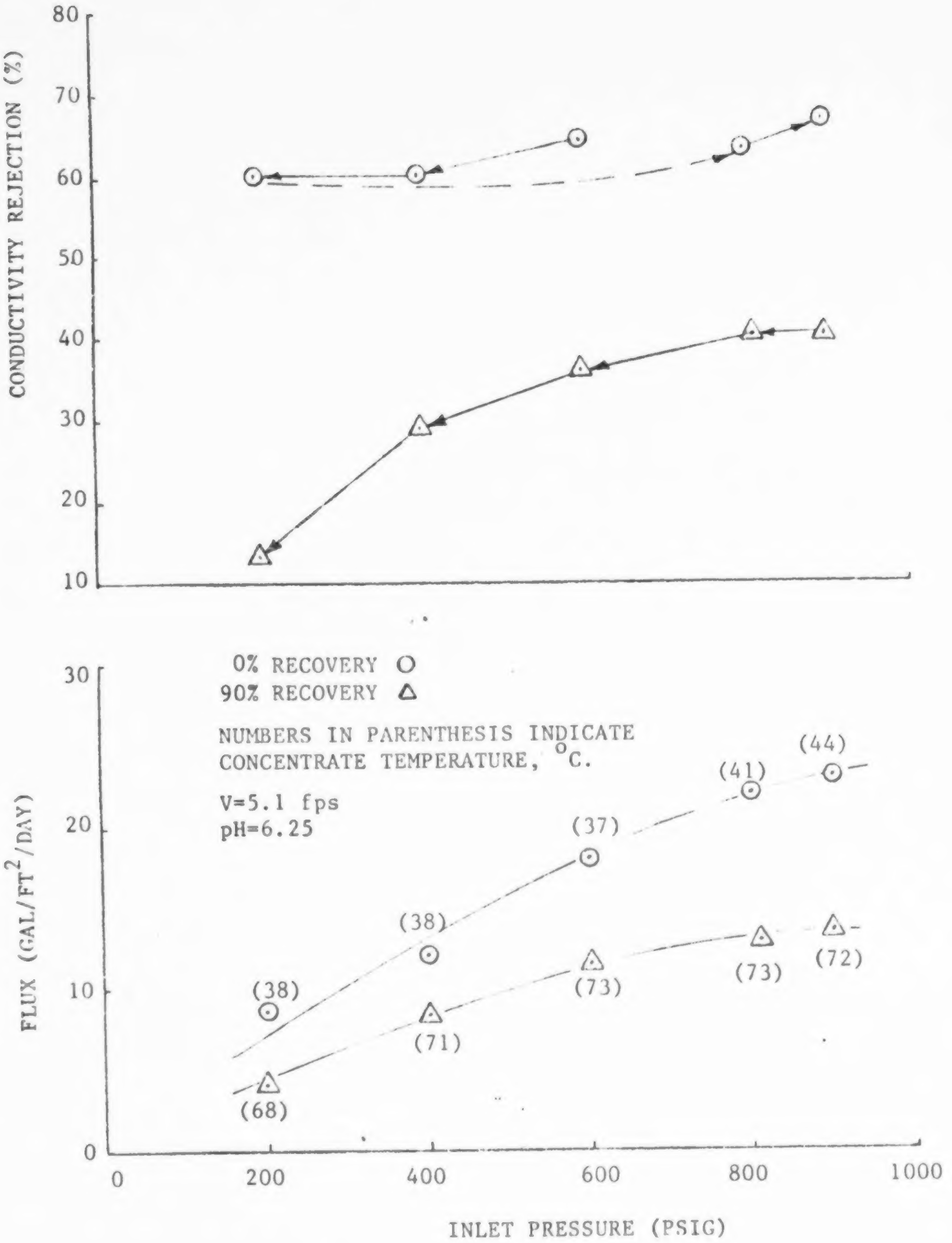


FIGURE 4. FLUX AND CONDUCTIVITY REJECTION VERSUS PRESSURE FOR MODULE NO. 540 (HF) OPERATED IN A STARCH DESIZE SOLUTION AT ZERO AND NINETY PERCENT RECOVERY.

ATTACHMENT - SAMPLING PROCEDURES

(1) Sample Collection and Storage:

Samples were collected in the one liter and 1 gallon bottles provided by S & P. The samples were immediately placed in the refrigerator at 36°F. Small amounts were taken from these samples for the analysis to be conducted by CARRE. Duplicates of samples No. 1, 4, 6, 8, 9, and 10 were collected using plastic 1/2 gallon milk containers and stored in the refrigerator. Those samples were kept until the shipped samples arrived at their destinations. Sample No. 10 was split and 1 liter was sent to Mill W-8.

(2) Shipping Instructions:

Ship by Federal Express, bill to third party, S & P Acct. No. 06007404.

Ship to: Dr. Charlotte Kimbraugh
Sverdrup Technology, Inc.
606 William Northern Blvd.
Tullahoma, TN 37388

1 liter sample of No. 10 will go to:

Mill W-8

Shipped on March 29, 1982.

The glass bottles were wrapped in the same manner as received, placed in a double thickness of plastic garbage bags with 5 pounds of ice, replaced in the coolers and receiving boxes.

PRELIMINARY TEST RESULTS SUMMARY SHEET

EFFLUENT STREAM: Starch Solution DATE TEST BEGUN: 3/29/82

MEMBRANE: ZOPA, Module No. 540 (HF)
ZOSS, Module No. N37 (UF)

TEST DURATION: 24 Hrs.

EFFLUENT PRETREATMENT: None

PRESSURIZING SYSTEM USED - HYPERFILTRATION UNIT, TYPE D, Fig. 1

BASE DATA USING 0.01M $NaNO_3$ SOLUTION

MODULE NO. 540 (HF)

	Pressure psig	Temperature ^0C	Flux $Gal/ft^2/day$	Conductivity Rejection, %
Before test	880	42	42	86%
After test	910	37	15	70%

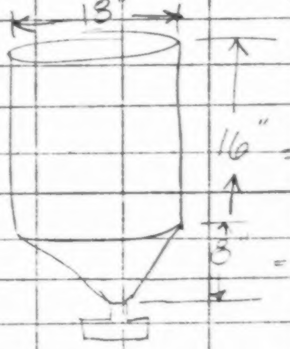
MODULE NO. N37 (UF)

	Pressure psig	Temperaure ^0C	Flux $Gal/ft^2/day$	Conductivity Rejection, %
Before test	880	42	105	45%
After test	910	37	21	48%

Sample Data:

Sample No.	Sample Type	Recovery, %
1	Feed - as received	-
2	Permeate - UF	0
3	Permeate - HF	0
4	Feed	0
5	Permeate - UF	80
6	Composite - HF Permeate	80
7	Concentrate	80
8	Permeate - UF	90
9	Composite - HF Permeate	90
10	Concentrate	90

DATE: 3/29/82 MODULE 540 + N37 LOOP 00151 Task: SVEEDRUP & PARCEL Page 1 of 9.

TIME	μ^F	GPM	Pin	Pout	$\overline{P}$	TEMP.	pH	ml/min	GFD	ζ	μ^P	% Rej	COMMENTS
0905	Begin pH 12 wash on loop.												
0925	End wash. Rinse loop.												
0930	Begin pH 2 wash on loop.												
1000	End wash. Begin flushing system to ~pH 7.												
1030	Install modules N37 (outlet) and 540 (inlet) and add 180 ml salt soln.												
1032	Pressuring system and allow T = ~37°C												
1115	2000	>4	880			42°C	6.85	2X182	42	.05	290	86%	540 HF
								2X224	105	.12	1100	45%	N37 UF Rince loop thoroughly.
1140	Tank filled to 16 in.* Start up. Raise to 600 psig. Collect sample no. 1.												
	* volume calc.												
									16" = 67 L 8" = 11.2 L				
										78 L volume in tank.			
1210-	2250		600			31°C	6.25	142	17	.028	550	76%	540
								62	15	.025	1200	47%	N37
1240	2250		600			37°C	6.25	158	18	.031	810	64%	540
								71	17	.028	1500	33%	N37 Begin P scan.
1257	2250		400			38°C	6.25	104	12	.030	910	60%	540
								61	14	.036	1550	31%	N37
1305	2250		200			38°C	"	76	8.8	.044	920	60%	540
								38	8.9	.045	1550	31%	N37
1314	2250		800			41°C	"	186	22	.027	830	63%	540
								82	19	.024	1550	31%	N37

DATE: 3/29/82 MODULE 540/N37 LOOP 00151 Task: SVERDRUP & PARCEL Page 2 of 4 8.6 in

<table>
<tr><th>TIME</th><th>μ^F</th><th>GPM</th><th>Pin</th><th>Pout</th><th>$\overline{P}$</th><th>TEMP.</th><th>pH</th><th>ml/min</th><th>GFD</th><th>r</th><th>μ^P</th><th>% Rej</th><th>COMMENTS</th></tr>
<tr><td>1321</td><td>2250</td><td></td><td>900</td><td></td><td></td><td>44°C</td><td>6.25</td><td>202</td><td>23</td><td></td><td>740</td><td>67%</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>86</td><td>20</td><td></td><td>1500</td><td>33%</td><td>collect samples 2, 3, 4</td></tr>
<tr><td>1338</td><td colspan="13">Sampling complete, begin concentrating by remove 4F (540) permeate to clean 30 gal SS tank Volume = (15.5 in × 4.2 L/in) + 11.2 L in cone = 76.3 L</td></tr>
<tr><td>1520</td><td>2700</td><td></td><td>900</td><td></td><td></td><td>64°C</td><td>6.25</td><td>182</td><td>21</td><td>.024</td><td>1300</td><td>52%</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>118</td><td>28</td><td>.031</td><td>1700</td><td>37%</td><td>(10.25 × 4.2) + 11.2 = 54.25 (29% Rec.)</td></tr>
<tr><td>1530</td><td colspan="13">Concentrate line came out of tank. Volume now (4" × 4.2) + 11.2 L 18L
Refill to 15.5". Restart & recirculate.</td></tr>
<tr><td></td><td colspan="13">At time of spill concentrate volume was 54.5 L @ 29% Recovery
After spill concentrate volume was 28 L @ 29%
54.5 L - 28 L = 26 L lost. To add same mass of constituent back to feed $(\frac{1}{1-.29}) \times 26\ L = 36\ L$ of new feed.
Tank volume 4" — must add 36 ÷ 4.2 or 8.6 in to total volume of 12.6 in + vol of cone.</td></tr>
<tr><td>1710</td><td></td><td></td><td>900</td><td></td><td></td><td>64°C</td><td></td><td>156</td><td>18</td><td>.020</td><td>—</td><td></td><td>540</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>102</td><td>24</td><td>.027</td><td>—</td><td></td><td>N37</td></tr>
<tr><td></td><td colspan="13">feed tank volume = (10.125" × 4.2 L/in) + 11.2 = 53.8 L
perm volume 29 in - 20.25 = 8.75" × 4.2 L/in = 36.8 L
} = 91 L (40% Rec.)</td></tr>
<tr><td>1830</td><td>3400</td><td></td><td>900</td><td></td><td></td><td>77°C</td><td>6.25</td><td>204</td><td>24</td><td>.026</td><td>1750</td><td>49%</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>106</td><td>25</td><td>.028</td><td>2200</td><td>35%</td><td></td></tr>
<tr><td></td><td colspan="13">feed tank (6.5 in × 4.2 l/in) + 11.2 = 38.5 L
perm vol. 29 in - 18.25 in = 10.75 × 4.2 = 45.2
} 84 L</td></tr>
<tr><td>1845</td><td colspan="13">Must remove 38.5 L - 19 L (75% Rec) = 19.5 L × 1000 ml/l = 19,500
13.5 hrs × 60 = 810 min = 19,500/810 = 24 ml/min to perm collection, recycle remainder back to feed. Lower to 500 psig and set perm flowrate at 20 ml/min. Cover tanks with plastic to minimize evaporative loss</td></tr>
</table>

DATE: 3/30/82 MODULE 540/N37 LOOP 00151 Task: SVERDRUP & PARCEL Page 3 of 4.

TIME	v^F	GPM	Pin	Pout	$\bar{P}$	TEMP.	pH	ml/min	GFD	ς	v^P	% Rej	COMMENTS
0730	(1½" × 4.2 L/in) + 11.2 = 17.5 L. Begin recycle.												Perm vol (29 - 13.75) × 4.2 = 64L
0735	4000		520			59°C	6.25	4X22	10.2	.020	2700	33%	
								32	7.5	.015	3400	15%	raise to 900 psig
0904	4000		890			67°C	•	2X76	18		2800	33%	
								2X26	12		3100	23%	begin collecting samples 5, 6, 7
0922	Sampling complete. New feed vol = (1" × 4.2) + 11.2 = 15.4L												
	New permeate vol. = 29 - 14.5 = 14.5 × 4.2L = 61L Begin concentrating												
	Last night the shell of 540 had to be filled in order to get												
	permeate splitter to work so after sampling the shell was allowed												
	to drain to initial level.												
0930	DKT raised module, but not filling product shell. Purpose = to have												
	minimum permeate volume in shell.												
0900	Stop Concentrating. Route perm to tank. Tank vol 7.0" in cone or L												
	Permeate vol = 29 - 12) × 4.2												Begin pressure.
0905	4500		900			72°C	6.25	2X58	13.5	.015	2700	40%	540
								2X19	8.9	.010	3100	31%	N37
0920	4500		810			73°C	6.25	2X56	13.0	.016	2700	40%	
								2X18	8.5	.010	3100	31%	
0930	4500		600			73°C	6.25	2X49	11.4	.019	2900	36%	
								2X17	8	.013	3200	29%	
0938	4500		400			71°C	"	73	8.5	.021	3200	29%	
								30	7.1	.018	3400	24%	
0945	4500		200			68°C	"	36	4.2	.021	3900	13%	
								21	4.9	.025	3500	22%	
1000	4500		900			72°C	"	2X49	11.4	.013	3600	20%	
								2X17	6	.009	3300	21%	begin collecting 8, 9 samples.
1045	Complete sampling including #10. Begin rinsing for salt pt.												

Reproduced from best available copy.

DATE: 3/30/82 MODULE 540/N37 LOOP 0057 Task: SVERDRUP & PARCEL Page 4 of 4.

TIME	℧^{F}	GPM	Pin	Pout	$\overline{P}$	TEMP.	pH	ml/min	GFD	τ	℧^{P}	% Rej	COMMENTS
1140	1600		910			37°C	6.30	42X3	15	.016	490	70%	540
								30X3	21	.023	840	48%	N37 Begin hot water wash on loop
	and modules.												
1250	End wash Drain flush & repeat												
1350	"		"		"		"		"				
1500	"		"		"		"		"				
1650	Shut down												
	3/31/82												
0830	1800		900			37°C	6.6	2X58	13	.015	540	70%	540
								2X38	18	.020	650	64%	N37 store modules.

MILL SURVEY REPORT
MILL W-9
WOVEN FABRIC FINISHING

SUMMARY

Mill W-9 is a woven fabric finishing mill that conducts several processes that have been investigated for the potential applicability of recycle/reuse technologies. Figure 1 illustrates the basic processes, summarizes the findings, and identifies further research needs. Table 1 illustrates the projected savings, costs, and paybacks associated with the recycle/reuse technologies considered at this mill.

The most promising technologies are:

1) recycle of batch dyeing rinsewater;
2) bleach bath reconstitution; and
3) dyebath reconstitution.

RECOMMENDATIONS

It is recommended that the following research needs be considered in future investigations:

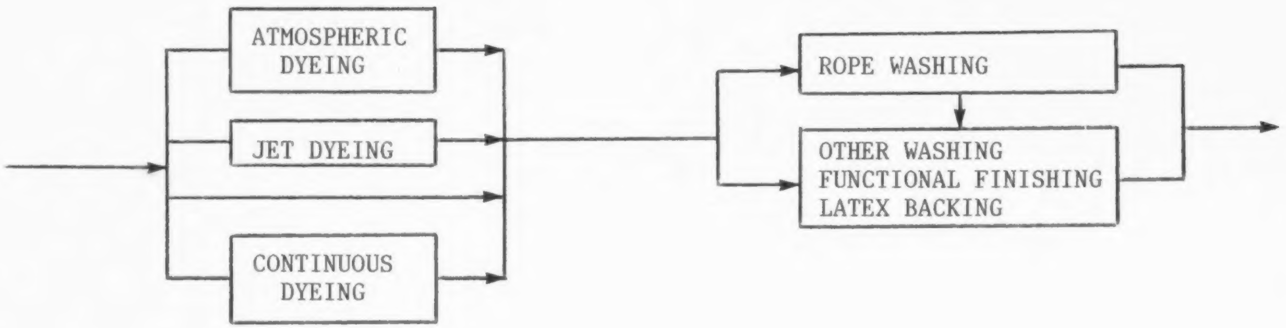
1. Identify effects on fabric quality of reuse of bleach baths, dyebaths, and rinsewater.

2. Determine the value of auxiliary chemicals in exhausted dyebaths.

3. Develop revised rinsing procedures in jet dyeing to accommodate dyebath reconstitution.

4. Investigate and resolve scheduling problems involved with dyebath reconstitution.

5. Should continuous dyeing begin to operate more frequently, a revised evaluation should be made to determine the value of recoverable chemicals, and pilot testing of hyperfiltration should be conducted to establish design criteria and reevaluate capital and O&M costs.


ATMOSPHERIC DYEING
JET DYEING
CONTINUOUS DYEING
ROPE WASHING
OTHER WASHING
FUNCTIONAL FINISHING
LATEX BACKING

Technologies Evaluated	Feasibility		Data Needs
	Technical	Economic	
Bleach Bath Reconstitution	Feasible	Marginal	Effects on Fabric Quality Value of Recovered Chemicals
Batch Dyeing - Rinse Water Recycle	Feasible	Promising	Effects on Fabric Quality
Dyebath Reconstitution	Feasible	Marginal	Effects on Fabric Quality Value of Recovered Chemicals
Continuous Dyeing - Dye Recovery by Hyperfiltration	Questionable	Not Promising	Pilot Test of HF; Dyehouse Operations; Value of Recovered Chemicals

FIGURE 1

TABLE 1

SUMMARY OF ECONOMIC AND ENVIRONMENTAL BENEFITS OF VARIOUS RECYCLE SCHEMES

Recycle/Reuse Scheme	Net Annual Savings (Costs)	Capital Cost	Payback (Years)	Flow Reduction	
				gpd	% total
Bleach Bath Reconstitution	$ 8,600	$ 31,500	3.7	14,000	5
Batch Dyeing Rinse Water Recycle	$ 21,600	$ 40,000	1.9	60,000	20
Dyebath Reconstitution	$ 18,500	$ 80,000	4.3	11,000	4
Continuous Dyeing-Dye Recovery by by Hyperfiltration	($110,000)	$ 982,000	no payback	60,000	*

* The continuous dye range was not in operation at the time of the field investigation at Mill W-9; results are from analysis of a similar operation at a sister mill, Mill W-10.

TABLE OF CONTENTS

Page

Summary ii

Table of Contents v

I. INTRODUCTION 1
  Facility Description 1
  Manufacturing Processes 1
  Overall Mass Balance 5
  Evaluation of Recycle/Reuse Technologies 8

II. RECONSTITUTION OF BLEACH BATHS 14
  Current Bleaching Procedure 14
  Proposed Modifications to Bleaching Procedure 14
  Technical Feasibility 14
  Economic Feasibility 18
  Environmental Benefits 20
  Conclusions 20

III. RECYCLE OF BATCH DYEING RINSE WATER 21
  Current Atmospheric and Jet Dyeing Procedures 21
  Proposed Modifications to the Batch Dyeing Rinsing Procedure 21
  Technical Feasibility 25
  Economic Feasibility 25
  Environmental Benefits 27
  Conclusions 27

IV. RECONSTITUTION OF DYEBATHS 29
  Atmospheric and Jet Dyeing Procedures 29
  Proposed Modifications for Dyebath Reconstitution 29
  Technical Feasibility 29
  Economic Feasibility 32
  Environmental Benefits 34
  Conclusions 34

TABLE OF CONTENTS (Continued)

Page

V. REUSE OF CONTINUOUS DYEING RINSE WATER 35
  Current Continuous Dyeing Procedure 35
  Proposed Modifications to Continuous Dyeing Operation 35
  Technical Feasibility 40
  Economic Feasibility 40
  Environmental Benefits 42
  Conclusions 42

SECTION I
INTRODUCTION

FACILITY DESCRIPTION

Mill W-9 is a woven fabric finishing mill that produces finished fabric for upholstery, drapery, and mattress ticking. The production processes include bleaching, dyeing, washing and functional finishing, and application of latex backing, as shown in Figure I-1. The major wet operations are bleaching, dyeing, and washing. Fabric weaving and preparation are conducted at other mills.

The primary fabric types are cotton/polyester blends, although other fibers are processed on occasion.

MANUFACTURING PROCESSES

Bleaching

Bleaching is performed as the first step in the batch dyeing process. Atmospheric becks or jet dye machines are used. Generally, hydrogen peroxide serves as the bleaching agent. Following bleaching, the exhausted bleach liquor is discharged from the dye machines, without dilution at a temperature of 150°F to 200°F. Further discussion of the bleaching operation is found in the section on bleach bath reconstitution.

Dyeing

The mill performs batch dyeing in atmospheric becks and pressure jet dye machines, and has facilities for continuous and jig dyeing. The continuous dye range was not in operation during the field investigations, so a similar continuous dye range at a sister mill (Mill W-10) was investigated. Jig dyeing is used primarily for occasional redyeing and is therefore not considered further in this study.

Atmospheric Dyeing. Dyeing in the atmospheric becks is a five stage operation: bleaching, rinsing, dyeing, clearing the beck, and rinsing. All of these operations produce wastewater.

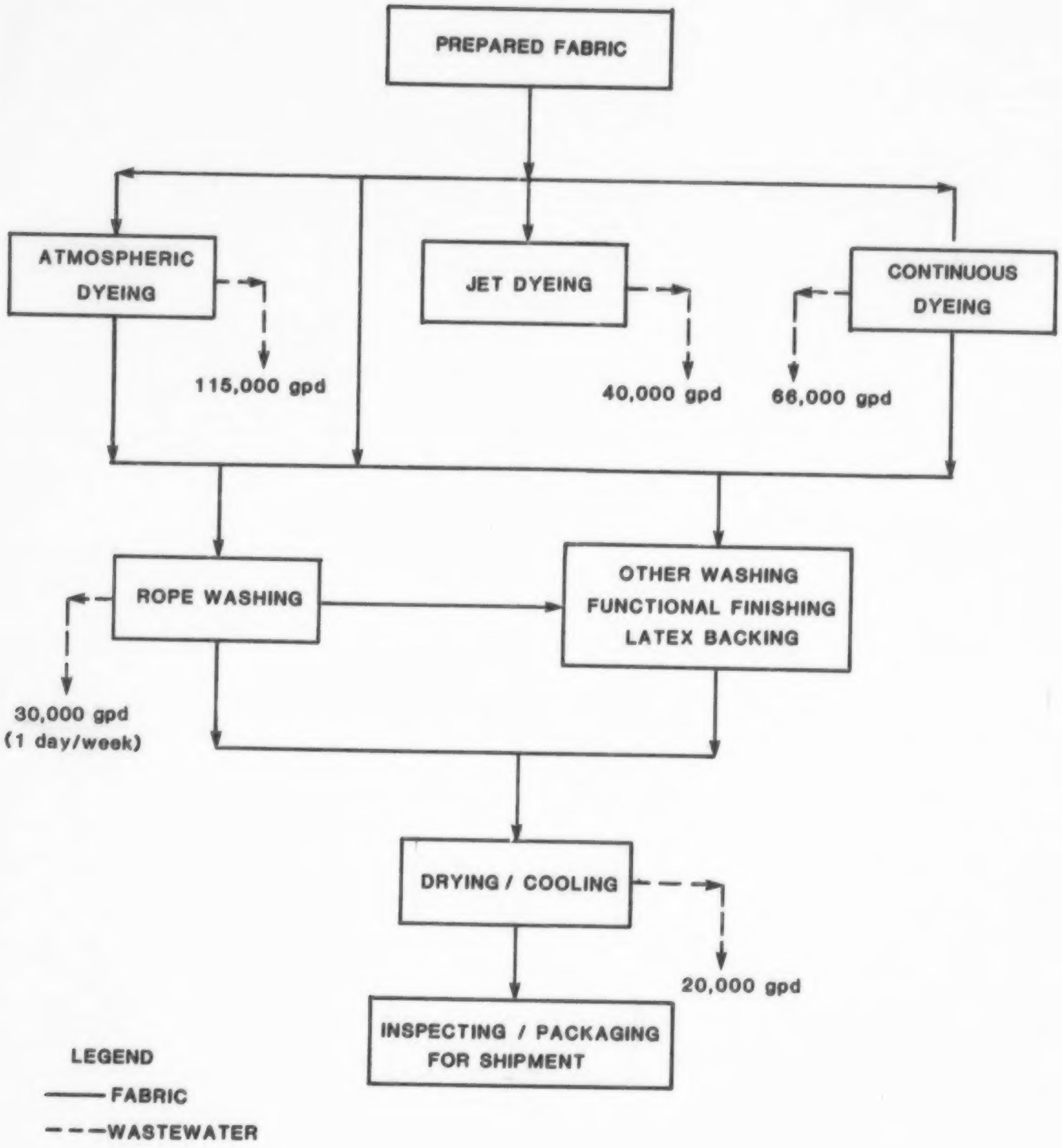

PREPARED FABRIC
ATMOSPHERIC DYEING
115,000 gpd
JET DYEING
40,000 gpd
CONTINUOUS DYEING
66,000 gpd
ROPE WASHING
30,000 gpd (1 day/week)
OTHER WASHING
FUNCTIONAL FINISHING
LATEX BACKING
DRYING / COOLING
20,000 gpd
INSPECTING / PACKAGING FOR SHIPMENT
LEGEND
FABRIC
WASTEWATER

FIGURE I-1 MANUFACTURING PROCESSES
MILL W-9

The initial bleaching and rinsing steps remove any remaining oils and size. However, desizing is not necessarily intended. Following discharge of the exhausted bleach bath, the beck is refilled in several stages with rinse water, and then dumped.

Dyeing of the fabric is then performed. The 1200 gallons of dyeing liquor consist of water, direct dyes, and a wetting agent. The temperature of the dye liquor is slowly raised from ambient to the 200°F dye strike temperature by steam. Ten pounds of dye liquor are used per pound of fabric.

To remove the hot exhausted dye liquor, 1200 gallons of rinse water are added slowly to the beck to displace the dye liquor. No sudden temperature changes are permitted in order to avoid spotting of the fabric and permanent wrinkles. This cooling rinse is generally followed by a second 1200-gallon rinse.

A final rinse of 1200 gallons then follows. Sometimes a salt solution is applied during this rinsing to fix the dye. Although hot water is used in this operation, the temperature of the wastewater is relatively low (around 100°F) because this hot rinse water is mixed with the cold rinse water in the beck to avoid sudden temperature changes within the becks.

The dyeing process is discussed further in the sections on recycle of dyebath rinse water and dyebath reconstitution.

Jet Dyeing. Jet dyeing is a four-stage process: bleaching, rinsing, dyeing, rinsing. It is a pressurized operation so that the temperatures are much higher than in atmospheric beck dyeing.

The bleaching operation consists of application of a hydrogen peroxide solution. Heat is applied through internal noncontact heat exchangers carrying steam. Cooling is done with the same heat exchangers carrying cold water. Following the bleaching operation the fabric is rinsed with running water at about 100°F.

Dyeing with dispersed dyes and a wetting agent is done in a thirty-minute cycle. Direct dyes and acid dyes are also sometimes used. The dye liquor to fabric ratio is about 10:1, although the mill is trying to reduce that ratio to 4:1. The maximum temperature of the dyebath is 240°F.

After dyeing, a salt water rinse is sometimes used to remove excess dyes and to fix the dye.

This process is also discussed further in subsequent sections.

Continuous Dyeing. Continuous dyeing consists of seven stages: scouring, dye application, setting, washing, salt application, drying, and cooling. The dyeing range is operated continuously throughout the day.

The scouring operation consists of a detergent wash followed by a rinse to remove any remaining oil and polyester-base size. The wastewater is discharged through a trough beneath the dye range.

Dye is applied by a dye pad. The dyeing chemicals consist mostly of direct dyes and an alcohol-base wetting agent. The wetting agent is about 0.1 percent of the dye bath. The dye pad box is discharged only during cleanup and it contains a very small amount of liquid.

After the dye is applied, the fabric passes through the setting stage. Heat is applied to set the dye; however, no wastewater results from this operation.

After setting the dye, the fabric passes through a series of wash boxes in which a water spray is applied to the fabric to rinse off excess dye. The washwater temperature is approximately 110°F on some ranges, and ambient temperatures on another range. Following washing the fabric passes through a salt spray to fix the dye.

The last two stages of dyeing consist of drying and cooling. The fabric is passed over and under cylinders through which steam or cold water passes in order to dry or cool the fabric. The steam is condensed within the cylinders, and the condensate is returned to the boiler. The cold water is not softened and recycle is not practiced in order to avoid buildup of scale and solids. Therefore, the cold water is discharged to the sewers.

Light shades are dyed before dark shades to avoid spotting the fabric. Pits on the cylinders retain dye which is transferred to the fabric. Dark shades can cover up spots caused by light shades but not vice versa.

Further discussion of the continuous dyeing operation is found in the section on dye recovery by hyperfiltration.

Washing and Finishing. Open width and rope washing are performed prior to application of functional finishes such as fire retardant and crease resistance. The rope washer is the predominant source of wastewater in this operation but it generates only about ten percent of total mill effluent when in operation. The rope washers use countercurrent rinsing. Other finishing operations use little water and are therefore not considered further in this study.

Much of the mill's wastewater originates from miscellaneous sources such as cooling cans in the finishing operations, but this is noncontact wastewater.

Latex Backing

Latex is applied to some fabric as a backing, and small amounts occasionally spill into the plant sewers. However, this is considered insignificant and is not discussed further herein.

OVERALL MASS BALANCE

Water Use and Characteristics

Total water use at the mill averages about 2.26 million gallons per week, or 450,000 gallons per day. The major individual areas of water use, as shown on Figure I-2, are the processes of atmospheric dyeing (140,000 gpd) and jet dyeing (48,000 gpd), which include a step for bleaching. Continuous dyeing facilities are available at this mill, but these were not in use during the field investigation. A similar range, however, was examined at a sister mill (Mill W-10). This range used about 77,000 gpd of water.

There is a large variety of finishing operations at the mill that incorporate rope and open width washing as preparation before finishing. The single most significant water use is for rope washing. This range operates about one day per week; on other days the other miscellaneous finishing ranges are in operation. The rope washing range uses about 36,000 gpd when in operation.

Water use for cooling, steam make-up, and sanitary purposes amounts to about 126,000 gpd.

Table I-1 lists the quality of the incoming city water.

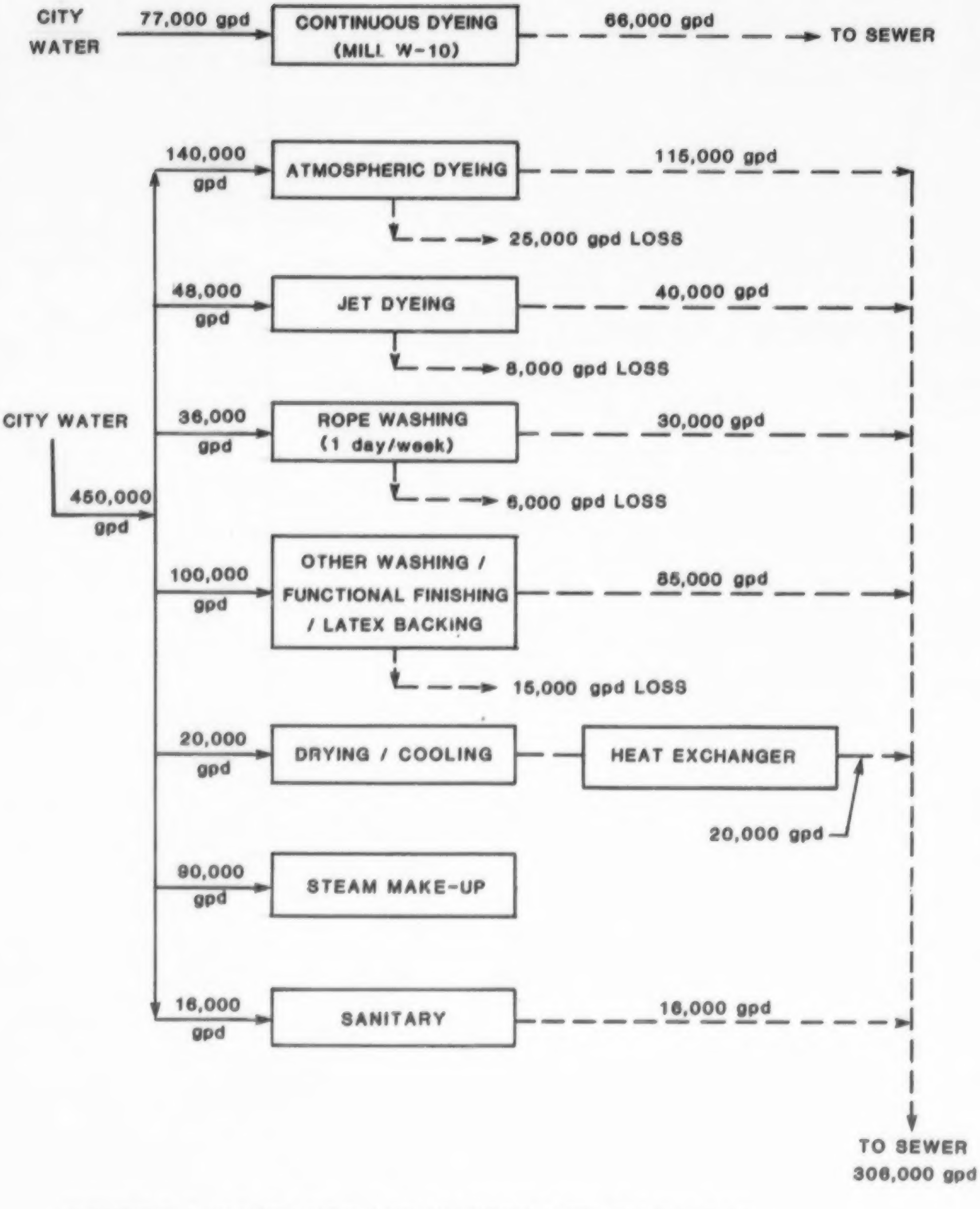

CITY WATER
77,000 gpd
CONTINUOUS DYEING (MILL W-10)
66,000 gpd
TO SEWER
140,000 gpd
ATMOSPHERIC DYEING
115,000 gpd
25,000 gpd LOSS
48,000 gpd
JET DYEING
40,000 gpd
8,000 gpd LOSS
CITY WATER
36,000 gpd
ROPE WASHING (1 day/week)
30,000 gpd
6,000 gpd LOSS
450,000 gpd
100,000 gpd
OTHER WASHING / FUNCTIONAL FINISHING / LATEX BACKING
85,000 gpd
15,000 gpd LOSS
20,000 gpd
DRYING / COOLING
HEAT EXCHANGER
20,000 gpd
90,000 gpd
STEAM MAKE-UP
16,000 gpd
SANITARY
16,000 gpd
TO SEWER
306,000 gpd

FIGURE I-2 WATER USE AND WASTEWATER DISCHARGE
MILL W-9

TABLE I-1
WATER QUALITY
FOR INCOMING CITY WATER

	Concentration, mg/l	
	Mill W-10	Mill W-9
Turbidity, NTU	0.34	1
pH, S.U.	6.9	7.3
Ca	4.2	3.8
Cu	0.005	0.1
Mg	1.7	3.0
Ni	0.0025	0.1
Na	18	20
Color (ADMI)	4	6.2
Alkalinity, as $CaCO_3$	10	34
Cl^-	11	8.5
Total BOD	--	7.4
COD	16	23
MBAS	--	0.007
Phenolics	<0.005	<0.040
TS	--	140
TDS	91	120
TSS	--	<1
Temperature, °F	45	52
Sulfate	32	--
Cr	0.003	--
Fe	0.12	--
Pb	<0.001	--
Mn	<0.1	--
Zn	0.10	--

Sources: W-10 sample collected 3/11/82
W-9 water samples collected 4/27/82 and 4/29/82.

Wastewater Discharge and Characteristics

The major sources of wastewater discharge are the same as the major water users. An estimated 15 percent of the water used in wet processing operations is lost through evaporation or retained in the fabric after wet processing, as indicated in Figure I-2.

Wastewater samples were collected and analyzed from the various stages of atmospheric and jet dyeing of Mill W-9, continuous dyeing rinse water at Mill W-10, and the rope washers and final effluent at Mill W-9. The results for conventional and nonconventional textile pollutants are presented in Table I-2 and discussed under the applicable recycle/reuse technologies. Tables I-3A and 3B present the overall pollutant loadings for the major wastewater streams to show the relative magnitudes contributed by each process. Table I-3A represents the loadings with the rope washer not operating (4 days per week), while Table I-3B shows the effect of rope washer operation (one day per week). The rope washer discharges a significant amount of BOD, COD, and TSS when in operation. Table I-4 presents the results for all parameters analyzed in the final effluent. Other constituents that affect recycle/reuse are discussed under the appropriate recycle/reuse technologies.

EVALUATION OF RECYCLE/REUSE TECHNOLOGIES

Reconstitution has been used in some textile mills to recycle batch bleach baths. Mill W-9 personnel believe that too few valuable chemicals are used to merit bleach bath recycle. However, energy and water savings may be significant. Bleach bath reconstitution is examined in Section II.

Bleaching and dyeing rinse water are frequently reused in a countercurrent fashion with continuous preparation and dyeing ranges. The same principle can be applied during batch dyeing by segregating the last half of each bleach rinse and each dye rinse and reusing the water as the first half of a subsequent rinse. This direct recycle is investigated further in Section III.

TABLE I-2

WASTEWATER CHARACTERISTICS

		Concentration (mg/l)				
Wastewater Source	Date	BOD	COD	TSS	Phenolics	pH (S.U.)
Bleaching						
Atm. Bleach Liquor	4/27/82	5	2,800	61	0.330	9.0
Atm. Bleach Rinse	4/28/82	14	110	--	< 0.040	7.7
Jet Bleach Rinse	4/28/82	5	210	3	--	6.9/8.8
Atmospheric Dyeing						
Dyebath	4/27/82	--	260	--	0.066	8.3/5.8
Dyebath	4/29/82	540	--	160	--	6.4
Salt Rinse	4/27/82	10	110	9	0.120	7.0
Dye Rinse	4/27/82	34	120	9	0.057	8.0/6.7
Jet Dyeing						
Dyebath	4/28/82	64	470	680	0.041	4.7
Dye Rinse	4/28/82	39	770	20	< 0.040	9.5/6.5
Rope Washer	4/28/82	280	1,610	1,330	0.050	6.3
Final Effluent	4/27/82	36	480	20	0.059	8.8
	4/28/82	64	630	160	< 0.040	6.7
	4/29/82	220	1,080	230	0.110	9.1
	Average	110	730	140	0.070	--
Continuous Dyeing*	3/11/82	60	140	16	< 0.005	9.5

*Continuous dyeing facilities at Mill W-9 were not in use during Phase II, so a similar operation at a sister mill (Mill W-10) was investigated.

TABLE I-3A
POLLUTANT LOADINGS*

Source	Flow		BOD		COD		TSS	
	gpd	% total	lb/day	% total	lb/day	% total	lb/day	% total
Atmospheric Dyeing	115,000	38	66	72	430	35	25	49
Jet Dyeing	40,000	13	7	8	127	10	21	41
Rope Washing	0	--	--	--	--	--	--	--
Cooling	20,000	6	--	--	--	--	--	--
Sanitary**	16,000	5	19	20	668	65	5	10
Other Washing & Finishing	115,000	38						
Final Effluent	306,000	100	92	100	1,225	100	51	100
Continuous Dyeing#	66,000	--	33	--	77	--	9	--

---

* Based on 4/27/82 sampling results, with rope washer not in operation. Rope washer operates about one day per week.

** Sanitary and other washing and finishing streams were not sampled.

# Continuous dyeing was not in operation at Mill W-9, so a similar operation was investigated at Mill W-10. The dye range was typically operating about 2 days per week.

TABLE I-3B
POLLUTANT LOADINGS[*]

Source	Flow		BOD		COD		TSS	
	gpd	% total	lb/day	% total	lb/day	% total	lb/day	% total
Atmospheric Dyeing	115,000	38	66	40	430	27	25	6
Jet Dyeing	40,000	13	7	4	127	8	21	5
Rope Washing	30,000	10	70	43	403	25	333	82
Cooling	20,000	6	--	--	--	--	--	--
Sanitary[**]	16,000	5	20	13	648	40	29	7
Other Washing & Finishing	85,000	28						
Final Effluent	306,000	100	163	100	1,608	100	408	100
Continuous Dyeing[#]	66,000	--	33	--	77	--	9	--

---

[*] Based on 4/28/82 sampling results, with rope washer in operation. Rope washer operates about one day per week.

[**] Sanitary and other washing and finishing streams were not sampled.

[#] Continuous dyeing was not in operation at Mill W-9, so a similar operation was investigated at Mill W-10. The dye range was typically operating about 2 days per week.

TABLE I-4
WASTEWATER CHARACTERIZATION
FINAL EFFLUENT

	Concentration (mg/l)		
	4/27/82	4/28/82	4/29/82
Turbidity, NTU	135	1000	40
pH, S.U.	8.8	6.7	9.1
Ca	1.5	1.0	1.2
Cu	< 0.1	< 0.1	< 0.1
Mg	2.0	7.1	11
Ni	< 0.1	< 0.1	< 0.1
Na	280	350	1,520
Color (ADMI)	377	537	114
Alkalinity, as $CaCO_3$	50	64	64
Cl^-	230	270	280
Total BOD	36	64	220
COD	480	630	1,080
MBAS	0.59	0.09	0.335
O&G	230	79	210
Phenolics	0.059	< 0.040	0.110
TS	690	1,180	1,040
TDS	510	880	730
TSS	20	160	230
Temperature, °F	95	108	100

Exhausted dyebaths can be reconstituted by adding fresh dyes and auxiliary chemicals. When this procedure is followed, water, energy, and chemical costs are reduced. Dyebath reconstitution is considered in Section IV.

Decoloring exhausted dyebaths by oxidation or adsorption is also possible. However, these techniques are more capital-intensive and less applicable to direct dyes than reconstitution. Therefore, they are not considered further for Mill W-9.

Continuous dyeing rinse water sometimes contains significant amounts of energy, dye, and auxiliary chemicals. Hyperfiltration recovers two fractions: a concentrate of the unexhausted dyes and chemicals and a clean hot permeate. Hyperfiltration is considered in Section V.

The rope washer flow is small and countercurrent rinsing is already used. Furthermore, the mill personnel report that few valuable chemicals are used. Therefore, recycling of the rope washer liquor is not considered further in this report.

SECTION II

RECONSTITUTION OF BLEACH BATHS

CURRENT BLEACHING PROCEDURE

As shown in Table II-1, bleaching is the first step of the dyeing process. The bleach bath is discharged from both the atmospheric and jet dyeing processes without dilution at a temperature of 150°F to 200°F. Table II-2 presents the bleach bath sampling results.

The 1100-gallon and 1600-gallon batches of bleach bath are discharged into concrete drain troughs which empty into the plant sewers. Recently, Mill W-9 has produced 12 batches per day from atmospheric dyeing and four or five batches per day from jet dyeing.

PROPOSED MODIFICATIONS TO BLEACHING PROCEDURE

As shown in Figure II-1, an insulated tank could be installed to store the waste bleach bath. Chemicals can be added to the bath to reconstitute it. The mill considers the amounts and proportions of peroxide, sodium silicate, caustic and acetic acid to be proprietary, so that further description is not provided herein.

TECHNICAL FEASIBILITY

Bleach bath reconstitution is practiced at a yarn mill investigated during this study. by Mill Y-4. Although some of the bleaching chemicals exhaust during use, some valuable chemicals and hot water are present in the discharge. Bleach bath reconstitution permits the reuse of these unexhausted chemicals and hot water.

After bleaching is performed at the above noted mill, the exhausted bleach bath is pumped to a holding tank while rinsing is separately performed in the original dye machine to complete the bleaching cycle. Once the bleached yarn is removed, and fresh yarn added to machine, the exhausted bleach bath is returned from the holding tank and reconstituted to initiate the next cycle. When a reconstitution sequence of bleaching is performed at this mill, the bleach bath is reconstituted over and over again until many cycles have been run or the mill is through with bleaching.

TABLE II-1

BATCH DYEING PROCEDURES

Description	Typical Water Use (gallons)	Comments
Atmospheric Dyeing Procedure		
Bleaching	1,600	H_2O_2, Na_2O x SiO_2, NaOH, acetic acid, 200°F
Rinse	3,600	in 3 stages 100°F
Dyeing	1,200	200°F and gradual cooling
Rinse	1,200	100°F
Rinse	1,200	100°F
Rinse	1,200	100°F, sometimes a brine rinse
Total	10,000	
Jet Dyeing Procedure		
Bleaching	1,100	H_2O_2, Na_2O x SiO_2, NaOH, acetic, acid, 200°F dumped at 150°F
Rinse	4,600	Running rinse 100°F
Dyeing	1,600	Dye, running rinse
Rinse (optional)	1,000	Salt sometimes
Total	8,300	

TABLE II-2
WASTEWATER CHARACTERISTICS
ATMOSPHERIC DYEING - BLEACH BATH*

Parameter	Concentration (mg/l)
Turbidity, NTU	140
pH (standard units)	9.0
Ca	1.5
Mg	5.6
Ni	<0.1
Na	400
Color (ADMI)	610
Alkalinity, as $CaCO_3$	300
Cl^-	85
Total BOD	4.8
COD	2,800
MBAS	0.3
O&G	69
Phenolics	0.330
TS	2,160
TDS	1,390
TSS	61
Temp. °F	170 to 195

Source: Composite-grab wastewater sample collected April 25, 1982.

*This is expected to be similar to bleach bath used in jet dyeing.

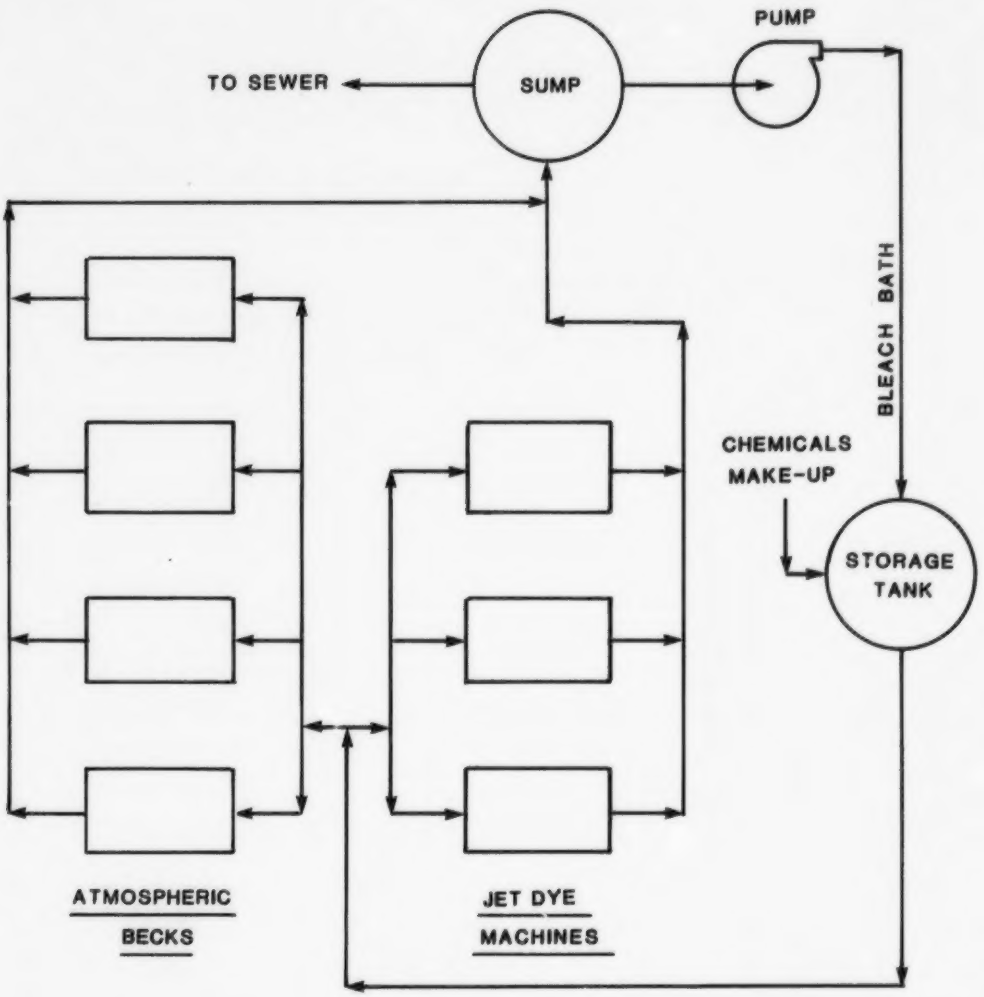

PUMP
TO SEWER
SUMP
BLEACH BATH
CHEMICALS
MAKE-UP
STORAGE
TANK
ATMOSPHERIC
BECKS
JET DYE
MACHINES

FIGURE II-1 SCHEMATIC OF BLEACH BATH RECONSTITUTION

Unlike dyeing, bleaching is very predictable and routine from one batch to the next. Batches do not need to be sequenced in a particular order as with dyeing, and hence production scheduling is not a consideration as long as there is bleaching to be done. Mill experience has shown that the quality of finished product is not affected by bleach reconstitution series of 10 cycles or more.

Effects on fabric quality need to be evaluated to confirm the technical feasibility of this technology at Mill W-9.

ECONOMIC FEASIBILITY

Cost savings are realized in the areas of water use, wastewater discharge, and energy. Chemical savings are likely, based on experience at the yarn mill, but Mill W-9 claims that the recoverable value will be insignificant and prefers to keep cost data confidential. In addition to the capital costs for the holding tank and related equipment (e.g., pump, piping, valves, etc.), a small additional operating cost for pumping will be experienced.

Table II-3 presents an analysis of the economics of bleach bath reconstitution. The basis of these costs and savings is as follows:

- o capital requirements for reconstitution include a 1,600-gallon, insulated, elevated fiberglass holding tank, pump, and plumbing modifications
- o holding tank and related equipment must be purchased (i.e., capital equipment not already available at mill)
- o reconstitution economics are developed for 4 atmospheric becks and 3 jet dyeing machines
- o bleach bath is used for bleaching ten batches of fabric before being discharged
- o mill operates 250 days per year
- o temperature of the recycled bleach bath is 150°F; the temperature of preheated city water is 130°F.
- o cost of water supply and sewer service is $1.43/1000 gallons

TABLE II-3
ECONOMIC ANALYSIS OF BLEACH BATH RECONSTITUTION

Capital		
1 1600-gal insulated tank		$ 5,200
1 pump		4,000
Piping and valves		13,000
Subtotal		$22,200
Contingencies, engineering, electrical, installation (42%)		9,300
Total		$31,500
Savings		$/yr
Chemical	(approximate)	0*
Energy, 5.8×10^8 Btu/yr		4,000
Water and sewer 3.5×10^6 gal/yr		5,000
		9,000
Operation and Maintenance		400
Net Annual Savings	(approximate)	$ 8,600
Payback Period		3.7 years

---

*Stated as zero chemical savings to adhere to mill comments that little chemical value will be recoverable. Mill claimed that details were confidential.

- energy costs are $6.72 per million Btu

As can be seen from the table, the payback period associated with bleach bath reconstitution at this mill is approximately 3.7 years. This payback could be shortened significantly by chemical savings, which have been ignored herein to adhere to confidentiality agreements.

ENVIRONMENTAL BENEFITS

The environmental benefits of bleach bath reconstitution are water use and wastewater discharge savings of 14,000 gpd, and energy savings of 2.3 million Btu/day. COD and phenols discharges are expected to be reduced fairly significantly, judging by the data in Table II-2, though actual effects need to be investigated during testing.

CONCLUSIONS

- Bleach bath reconstitution has been successful in bleaching of yarn at another mill investigated during this project, and these results should be tested for applicability at this mill.
- With a maximum payback period of 3.7 years, the economics of reconstitution at this mill are marginally attractive. Taking the value of recoverable chemicals into consideration will lower this payback period.
- Significant environmental benefits result from the implementation of bleach bath reconstitution.

SECTION III

RECYCLE OF BATCH DYEING RINSE WATER

CURRENT ATMOSPHERIC AND JET DYEING PROCEDURES

Table III-1 presents the water usage in typical batch dyeing operations at Mill W-9. As shown in Table III-1, rinsing follows both bleaching and dyeing. The entire dyeing cycle, including bleaching, dyeing, and rinsing, is controlled by computer. The programmed total flows for the atmospheric and jet dyeing procedures are usually about 10,000 gallons per batch and 8,300 gallons per batch, respectively. However, during the field investigation, flows in the atmospheric and jet dyeing procedures were observed to be 13,300 gallons per batch and 12,900 gallons per batch, respectively. This extra water use was probably due to additional rinsing.

The rinse water discharges from each dye machine through a pipe into concrete drain troughs. The drain troughs empty into the plant sewers.

Table III-2 presents the rinse water characteristics. Note that the rinse water after bleaching contains relatively few organic pollutants (low BOD and COD concentrations), few suspended solids, little or no color, and only a modest increase in dissolved solids over the city water concentration (120 mg/l). Similarly, the dye rinse water from atmospheric beck dyeing contains little color, suspended solids, or organics, but does contain a higher level of dissolved solids. Rinse water following jet dyeing contains substantial color, organics, and dissolved solids. This is due to the use of an overflow, or running, rinse in which the exhausted dyebath is not dropped before rinsing begins. The residual color may limit reuse of this jet dyeing rinse water.

PROPOSED MODIFICATIONS TO THE BATCH DYEING RINSING PROCEDURE

During sampling, the last half of each rinse appeared to be clean water. For example, the salt rinse is the last rinse to occur in the batch dyeing process. The salt rinse (Table III-3) has a color of only 10.2 ADMI units and little suspended solids or organics. The last

TABLE III-1

BATCH DYEING PROCEDURES

Description	Typical Water Use gallons	Comments
Atmospheric Dyeing Procedure		
Bleaching	1,600	H_2O_2, Na_2O x SiO_2, NaOH, acetic acid, 200°F
Rinse	3,600	in 3 stages 100°F
Dyeing	1,200	200°F and gradual cooling
Rinse	1,200	100°F
Rinse	1,200	100°F
Rinse	1,200	100°F, sometimes a brine rinse
Total	10,000	
Jet Dyeing Procedure		
Bleaching	1,100	H_2O_2, Na_2O x SiO_2, NaOH, acetic acid, 200°F dumped at 150°F
Rinse	4,600	Running rinse 100°F
Dyeing	1,600	Dye, running rinse
Rinse (optional)	1,000	Salt sometimes
Total	8,300	

TABLE III-2

WASTEWATER CHARACTERIZATION
BLEACH AND DYE RINSE WATER

Parameter	Concentration (mg/l)		Concentration (mg/l)	
	Atmospheric	Jet	Atmospheric	Jet
Turbidity NTU	4.4	12	11	1.4
pH (Standard units)	7.7	6.9 & 8.9	8 & 6.7	9.5 & 6.5 & 6.5
Ca	0.25	1.6	0.66	0.58
Cu	< 0.1	--	< 0.1	0.59
Mg	0.1	1.8	0.17	0.13
Ni	< 0.1	--	< 0.1	< 0.1
Color (ADMI)	22	48.6	82.9	775
Alkal. as $CaCO_3$	33	62	32	42
Cl	840	8.5	880	1,040
Total BOD	14	4.6	34	39
Soluble BOD	--	6.4	--	--
COD	110	210	120	770
MBAS	--	0.33	2	0.02
O&G	--	40	--	--
Phenolics	< 0.040	--	0.057	< 0.040
TS	--	310	1,650	2,070
TDS	--	250	1,540	1,970
TSS	--	3	9	20
Temp °F	82	100 to 109	95 to 104	102 to 115
Flow, gpd	45,000	21,000	46,000	12,000

TABLE III-3

WASTEWATER CHARACTERIZATION

ATMOSPHERIC DYEING - SALT RINSE*

Parameter		Concentration (mg/l)
Turbidity	NTU	2
pH (Standard units)		7
Ca		0.88
Cu		<0.1
Mg		0.18
Ni		<0.1
Na		1,180
Color (ADMI)		10.2
Alkal. as $CaCO_3$		25
Cl		210
Total BOD		10
Soluble BOD		
COD		110
MBAS		0.17
O&G		
Phenolics		0.120
TS		2,798
TDS		2,743
TSS		8.8
Temp °F		75

*A final rinsing step used on a portion of production to fix the dyes.

half of the bleach and dye rinses were observed to be of a similar nature. This relatively clean rinse water could be reused as the first half of a subsequent rinse, and then be discharged, although the dissolved solids content may limit the amount of rinse water that can actually be reused. As shown in Figure III-1, pipes and valves could be installed at a sump so the wastewater could be pumped to one of two elevated storage tanks in the dyehouse. The system would be controlled by the dye cycle computer. Each storage tank should be one-half the volume of the maximum rinse. One tank would retain bleach rinse while the other would retain dye rinse. The stored water could flow by gravity back to the dye machines during a subsequent rinse.

TECHNICAL FEASIBILITY

Continuous preparation and dye ranges commonly use countercurrent rinsing. Reusing the last half of batch rinsing would be a similar application. In fact, this method is mentioned in a patent owned by Hanes Corporation (Patent No. 4,152,113, May 1, 1979). Furthermore, a few carpet mills using atmospheric beck dyeing have reused the final rinse water for dyebath make up. The above mentioned patent also indicates that rinse water can be used as dye bath make up water.

The salt content of the rinse waters needs to be studied for its effects on the quality of dyeing. Salt buildup in reuse would need to be carefully monitored.

ECONOMIC FEASIBILITY

Cost savings result from water savings and sewer use charge reductions. Energy savings are not expected from reuse because rinse water used generally has a temperature of only 77 to 104°F. The economic analysis presented in Table III-4 is based on the following:

o Use of the second half of all rinse waters as make-up for the first half of the subsequent rinse. The second portion of the subsequent rinse will use city water, which in turn is reused for the next rinse cycle.

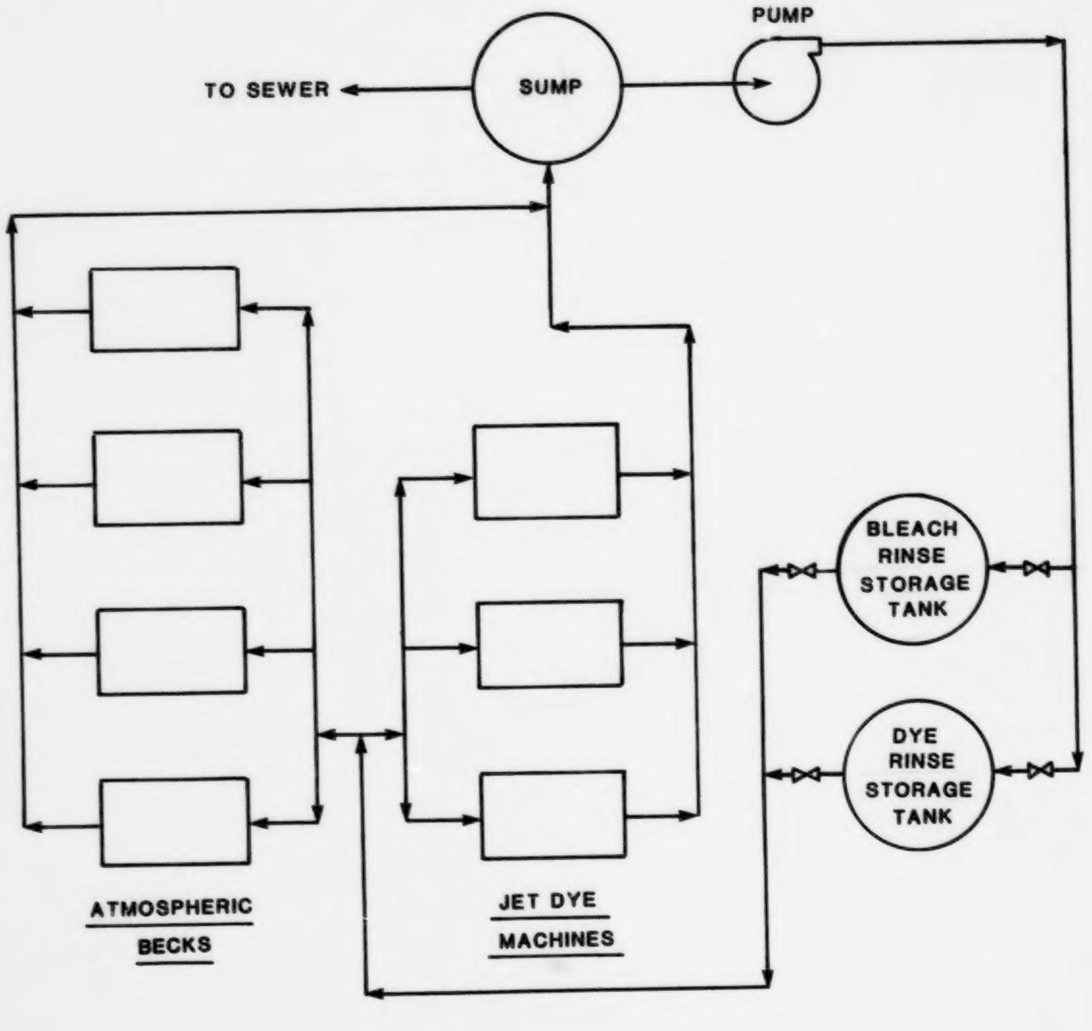

PUMP
TO SEWER
SUMP
BLEACH RINSE STORAGE TANK
DYE RINSE STORAGE TANK
ATMOSPHERIC BECKS
JET DYE MACHINES

FIGURE III-1 SCHEMATIC OF RINSE WATER RECYCLE SYSTEM

- Water service and sewer use savings of $1.43/1000 gallons.
- Mill operates 250 days per year.

Capital expenditure will be required for piping and valves, a pump, and two 2,300-gallon insulated tanks. As shown in Table III-4, the capital costs will be about $40,000. The net annual savings for this system would be about $21,600. Thus, a payback period of about 1.9 years can be expected, which makes the system reasonably attractive for the mill.

ENVIRONMENTAL BENEFITS

Direct recycle and reuse of rinse water will reduce the amount of water used and wastewater discharged by 60,000 gpd or 20 percent of total plant discharge. However, the mass of pollutants discharged will remain unchanged while their concentrations will increase slightly due to the smaller flow.

CONCLUSIONS

- Effects of salt content of rinse waters on fabric and dyeing quality must be carefully evaluated to confirm the technical feasibility of this technology.
- Actual water savings must be determined through testing to establish the blowdown necessary to avoid deterioration of fabric quality.
- A detailed estimate of capital expenditures is needed to confirm economic feasibility.

TABLE III-4

ECONOMIC ANALYSIS OF RINSE WATER RECYCLE

Capital	
2 2300-gal insulated tanks	$11,000
1 pump	4,000
Piping and valves	13,000
Subtotal	$28,000
Contingencies, engineering, electrical, installation (42%)	12,000
Total	$40,000
Annual Savings	
Sewer and water (half of bleach and dye rinse) 15×10^6 gallons/year (60,000 gpd)	$22,000
Annual Operation and Maintenance Costs	
Electricity - negligible	
Pump repairs, 10% of capital	$ 400
Net Annual Savings	$21,600
Payback Period	1.9 years

SECTION IV
RECONSTITUTION OF DYEBATHS

ATMOSPHERIC AND JET DYEING PROCEDURES

As explained in the preceding sections, atmospheric dyebaths are usually discharged without dilution. However, the jet dyebaths are diluted by a running rinse. The temperature of the atmospheric dyebath at discharge is usually about 180°F, while the temperature of the jet dyebath just before the running rinse starts is about 150°F.

Table IV-1 presents the characteristics of spent dyebaths. The data show these dyebaths to be highly colored and to contain high dissolved solids concentration and some organics. These are due to auxiliary chemicals and unexhausted dyestuffs remaining in the dyebath after dyeing.

The dyebaths are discharged from the dyeing machines through the same drains used for the rinse water.

PROPOSED MODIFICATIONS FOR DYEBATH RECONSTITUTION

Exhausted dyebaths usually contain 80 percent of the auxiliary chemicals and five percent of the original dyes. These dyebaths can be recycled after the addition of fresh chemicals and dyes. Of course, fewer chemicals will be used, and energy (hot water) will be conserved. To accomplish this reconstitution, pipes, valves, pumps, and insulated storage tanks are required, as indicated in Figure IV-1. The volume of each storage tank should equal the volume of one batch of dye liquor 1000 to 1200 gallons. In addition, a spectrophotometer and microcomputer are required to determine the quantity of make-up dye.

TECHNICAL FEASIBILITY

Dyebath reconstitution is in full-scale use at a number of textile mills. Pilot scale tests have been performed at many other mills that indicate favorable results. A significant amount of research has been performed by Georgia Tech and is described in more detail in the Final Project Report. Scheduling and quality control problems are

TABLE IV-1

DYEBATH WASTEWATER CHARACTERISTICS

Parameter	Concentration (mg/l) Atmospheric Dyeing	Concentration (mg/l) Jet Dyeing
Turbidity, NTU	16	< 1
pH, standard units	5.8 to 8.3	4.7
Ca	1.6	1.9
Cu	< 0.1	3.8
Mg	0.28	0.14
Ni	< 0.1	0.12
Na	900	5,200
Color (ADMI)	3,750	2,740
Alkal. as $CaCO_3$	46.2	0
Cl	2,980	5,200
Total BOD	540	64
COD	260	470
MBAS	34	0.15
O&G		110
Phenolics	0.066	0.041
TS	7,200	9,730
TDS	6,590	8,830
TSS	160	680
Temp °F	180 to 198	167
Flow	10,000 gpd	3,200 gpd

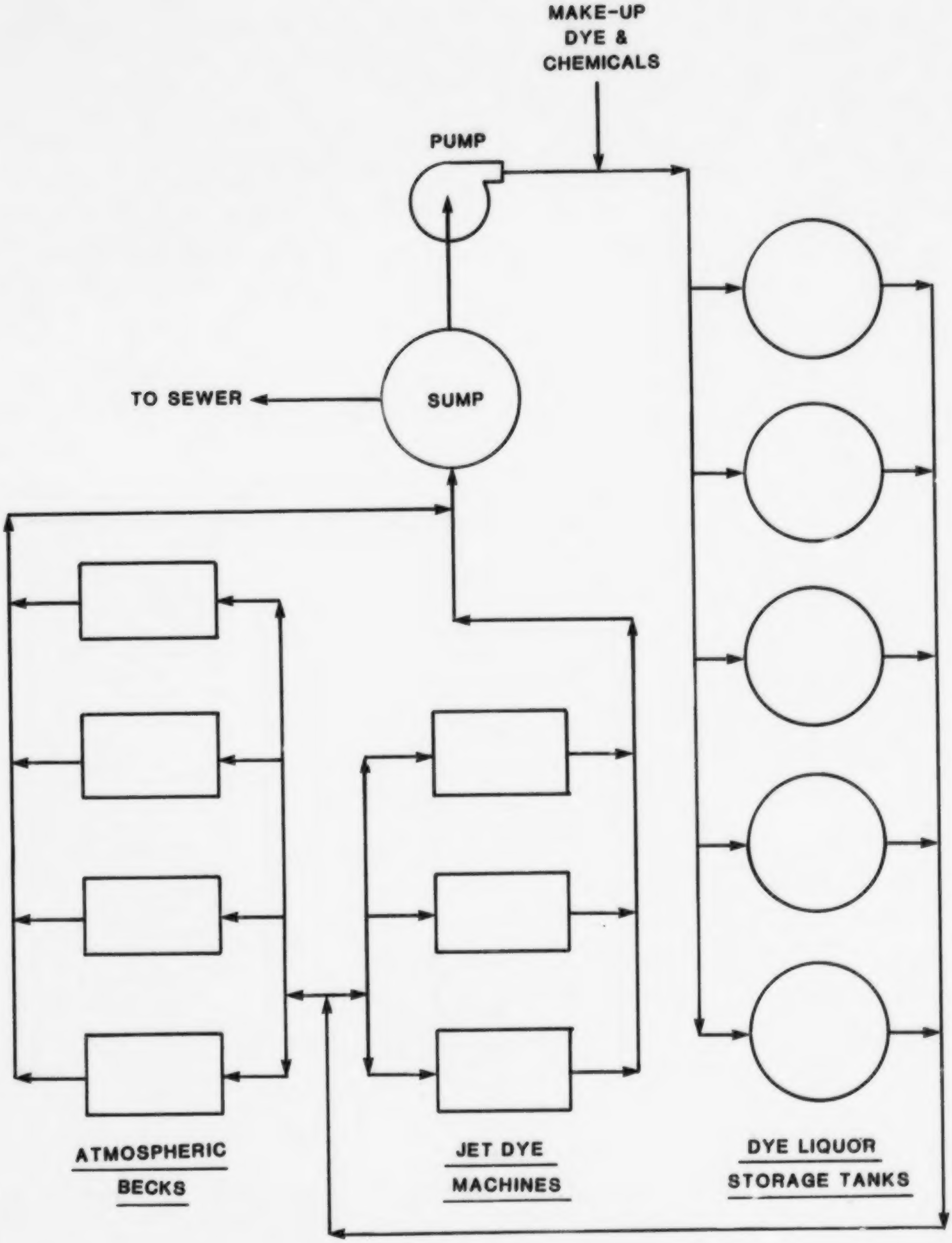

MAKE-UP
DYE &
CHEMICALS
PUMP
TO SEWER
SUMP
ATMOSPHERIC
BECKS
JET DYE
MACHINES
DYE LIQUOR
STORAGE TANKS

FIGURE IV-1 SCHEMATIC OF DYE BATH RECONSTITUTION

the most likely reasons that reconstitution has not been widely accepted. However, a few textile industry experts believe that quality control and scheduling problems can be overcome in most circumstances. It must be approached on a case-by-case basis, following a methodology being developed during Phase III of this study. Revised rinse procedures in jet dyeing must be developed to accommodate reconstitution. A running rinse as used currently causes dilution of the dyebath, which would render the bath inappropriate for reuse.

ECONOMIC FEASIBILITY

Cost savings are realized in the areas of water use, wastewater discharge, energy savings, and auxiliary chemical use. In addition to the capital costs for the seven 1500-gallon holding tanks, pump, piping, valves, spectrophotometer, and microcomputer, additional expenses will be encountered for pumping and other operating costs. Some developmental costs, primarily research labor, will also be required.

Table IV-2 presents an analysis of the economics of basic dyebath reconstitution. The basis of these costs and savings is as follows:

- capital requirements for reconstitution include seven 1500-gallon, insulated, elevated fiberglass holding tanks, pump, plumbing modifications, and spectrophotometer and microcomputer
- holding tanks and related equipment must be purchased (i.e., capital equipment not already available at the mill)
- reconstitution economics developed for seven dye machines
- dyebath used for dyeing five batches before being discharged
- 80 percent water savings expected
- cost of water service and sewer use is \$1.43/1000 gallons
- surfactant present at 0.1% of dyebath and valued at \$0.35/lb Other chemical values not given by mill and stated to have little value

TABLE IV-2

ECONOMIC ANALYSIS OF DYEBATH RECONSTITUTION

Capital			
7 1500-gal insulated tanks			$30,000
1 pump			4,000
Piping and valves			13,000
Analysis equipment			9,000
Subtotal			56,000
Contingencies, engineering, electrical, installation (42%)			24,000
Total Capital			80,000
Savings	$/year		
Chemicals, surfactant: 23,000 lb/yr	8,000		
Energy, 1.8×10^9 Btu/yr	12,000		
Water and sewer, 2.7×10^6 gal/yr	3,900		
		23,900	
Operation and Maintenance		5,400	
Net annual savings			18,500
Payback period			4.3 years

- energy costs are \$6.72 per million Btu
- incoming water at 100°F; exhausted dyebath water at 190°F

As can be seen from the table, the payback period associated with this reconstitution scheme is approximately 4 years. This is a relatively long payback period for this recycle technology. The most significant factor affecting the payback period is the low value of recoverable auxiliary chemicals at this mill. The mill states that other chemicals have little value and are not to be used in estimates of recoverable value.

ENVIRONMENTAL BENEFITS

With a reconstitution system employing 5 cycles, only about 20 percent of the water normally used for dyeing will be discharged, while most of the chemicals will remain with the recycled dyebath instead of being discharged. Therefore, reconstitution will cause a reduction in the volume of wastewater discharged. The above analysis estimated a reduction in wastewater flow of about 11,000 gpd or 4 percent of the mill total. However, the actual mass of pollutants that will be discharged depends on the buildup of these pollutants through a reconstitution series. This is in need of further research to determine actual pollutant reductions.

CONCLUSIONS

- Dyebath reconstitution has been successful at full scale at other mills, but effects on fabric quality and scheduling must be investigated to confirm technical feasibility at this mill.
- The long payback period is sensitive to actual chemical savings, which should be evaluated in more detail by mill personnel when considering this technology.
- Environmental benefits can be expected in terms of water and energy savings, but reduction in pollutant discharge is in need of further investigation to determine the buildup of pollutants over a reconstitution series.

SECTION V

REUSE OF CONTINUOUS DYEING RINSE WATER

CURRENT CONTINUOUS DYEING PROCEDURE

There is one continuous dyeing range at Mill W-9. However, it has not been used for several months, and its operation is not anticipated in the near future, according to company plans. A sister mill, Mill W-10, uses three continuous dyeing ranges. The equivalent of one of these ranges is operated two days a week, that is, these ranges are operated far below capacity. One of the ranges uses a once-through cold spray rinse while the other two ranges use countercurrent flow wash boxes (Figure V-1). All three ranges use brine tanks to apply a continuously recycling salt rinse to fix the dyes. The rinse water discharge flow rate is estimated to be about 66,000 gallons per day. Table V-1 presents the wastewater characteristics.

The dye pad box contains direct dyes and a wetting agent, a sulfosuccinate compound.

PROPOSED MODIFICATIONS TO CONTINUOUS DYEING OPERATION

A hyperfiltration system could be installed to concentrate the rinse water into two fractions: concentrate that can be reused as dye makeup, and permeate that can be reused as rinse water.

The system would consist of a raw wastewater storage tank, a high pressure pump, a hyperfiltration unit, a permeate storage tank, a concentrate storage tank, and miscellaneous piping. Figure V-2 is a schematic of the proposed system. Table V-2 lists the equipment and design criteria.

The raw waste holding tank should be large enough to hold dye range waste during a hyperfiltration unit shutdown. The proposed system is similar to one currently operating at LaFrance textile mill. It shuts down 30 minutes per day for cleaning. Therefore, the raw waste storage tank should be sized for a 30-minute flow--about 1000 gallons.

Similarly, the permeate storage tank is sized to supply water to the dye ranges during cleaning of the unit--about 1000 gallons.

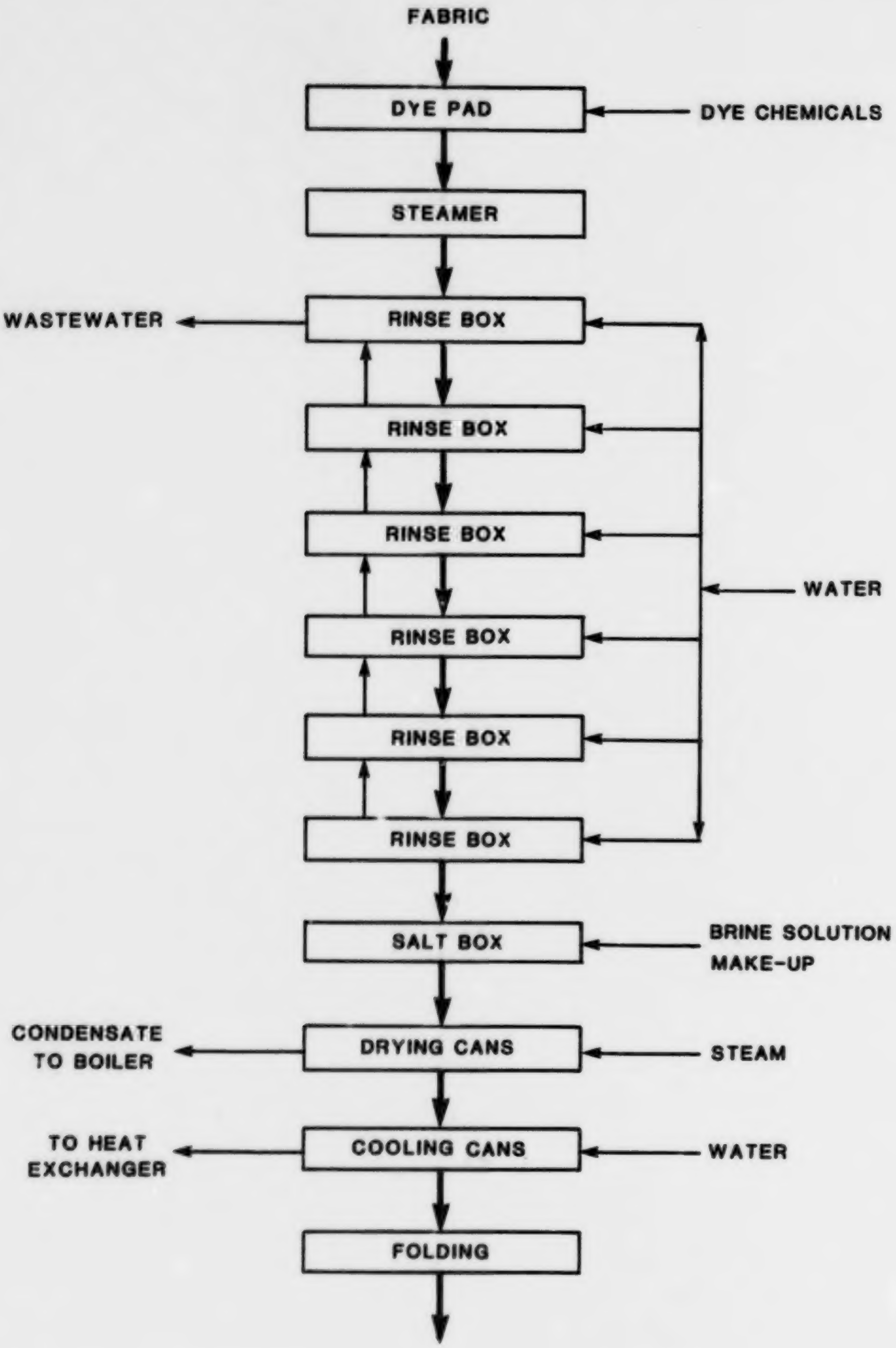

FABRIC
DYE PAD
DYE CHEMICALS
STEAMER
WASTEWATER
RINSE BOX
RINSE BOX
RINSE BOX
WATER
RINSE BOX
RINSE BOX
RINSE BOX
SALT BOX
BRINE SOLUTION
MAKE-UP
CONDENSATE
TO BOILER
DRYING CANS
STEAM
TO HEAT
EXCHANGER
COOLING CANS
WATER
FOLDING

FIGURE V-1 SCHEMATIC OF CONTINUOUS DYEING RANGE

TABLE V-1
CONTINUOUS DYEING WASTEWATER CHARACTERISTICS

Parameter	Concentration (mg/l)
Turbidity, NTU	10
pH, standard units	9.5
Ca	5.6
Cu	0.95
Mg	1.5
Ni	< 0.0025
Na	240
Color (ADMI)	290
Alkal. as $CaCO_3$	44
Cl	87
Total BOD	60
COD	140
MBAS	6.3
Phenolics	< 0.005
TS	620
TDS	580
TSS	16
Temp. °F	50
Sulfate	220
Cr	0.004
Fe	0.25
Pb	< 0.001
Mn	< 0.1
Zn	0.12

Source: Wastewater sample collected 3/11/82 at Mill W-10.

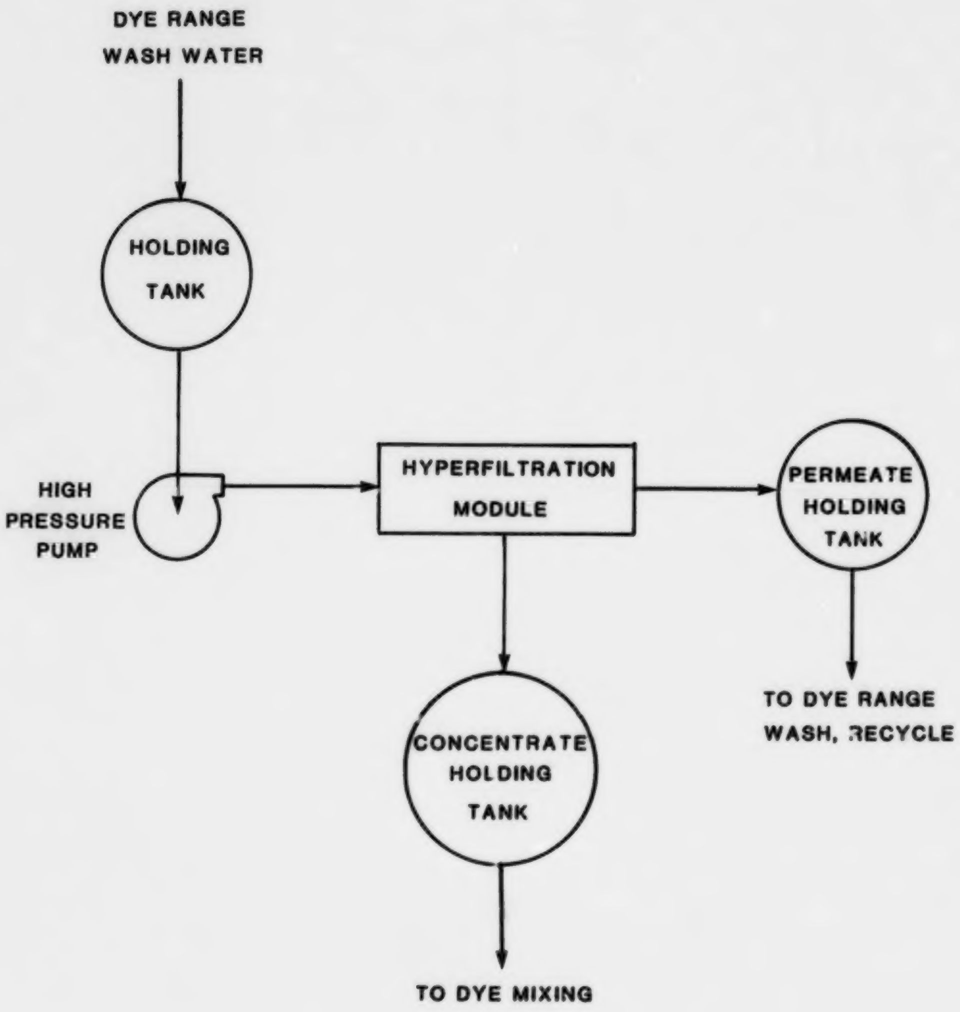

DYE RANGE WASH WATER
HOLDING TANK
HIGH PRESSURE PUMP
HYPERFILTRATION MODULE
PERMEATE HOLDING TANK
TO DYE RANGE WASH, RECYCLE
CONCENTRATE HOLDING TANK
TO DYE MIXING

FIGURE V-2 HYPERFILTRATION SYSTEM

TABLE V-2

EQUIPMENT NEEDED TO RECYCLE CONTINUOUS DYEING WASTEWATER

Description	Design Criteria
Hyperfiltration unit and high pressure pump*	66,000 gpd
Raw waste holding tank	1,000 gal
Permeate holding tank	1,000 gal
Concentrate holding tank	200 gal
Interconnecting steel pipe, fittings, and valves	2,000 ft

*Note that design of the unit depends on flux rate, which is influenced by temperature. The one range investigated at Mill W-10 uses a cold spray rinse, so it is conceivable that the feed to the hyperfiltration unit will have to be heated to yield a reasonable flux rate. This factor and other factors, such as length of dyeing runs and time between runs, will determine actual design. These factors need to be investigated during pilot testing.

TECHNICAL FEASIBILITY

A full-scale hyperfiltration facility has recently been put into service at LaFrance Industries (Riegel Textile Corp.). Preliminary reports indicate that separation and recovery of the dyestuff from the rinse water has been successfully achieved. The recovered rinse water can be recycled to provide water, sewer use, and energy savings. Efforts to reuse the recovered dyestuff have not been completely successful. Work at LaFrance is continuing. The LaFrance system is a hollow tube system with a zirconium oxide polyacrylate membrane. It is capable of operating at high temperatures and high pH. However, wastewater at Mill W-10 is not excessively hot or high in pH. Therefore, other membranes may be more suitable at Mill W-10. Further discussion of the LaFrance installation and general applicability of HF is found in Volume 1.

Design parameters include flux rate, temperature, and pressure. Pilot tests are necessary to determine these parameters. Since production appears to be subject to variation, it is difficult to establish a schedule for operation of the hyperfiltration unit and to determine the appropriate size of the unit. Generally, long runs of a single dye type provide the optimum conditions for economical operation.

ECONOMIC FEASIBILITY

Cost savings from recycle/reuse of continuous dyeing rinsewater can result from water and sewer charge savings, energy savings, and chemical recovery. Operating costs result from operation of the hyperfiltration system. Capital costs include estimates for the hyperfiltration unit and high pressure pump, holding tanks, and interconnecting piping, fittings, and valves. The costs and savings summarized in Table V-3 are based on the following:

- Capital and O&M costs as developed in Volume 1.
- Water service and sewer charges = $1.43/1000 gallons
- No energy savings expected, because dye rinsewater is cold.
- Chemical recovery - direct dyes in the rinsewater assumed to be 0.5% of the dye applied. Average dye applied is 250 lb/day. Value of dye = $3.00/lb.

TABLE V-3

ECONOMIC ANALYSIS OF HYPERFILTRATION

Capital		
HF module and high pressure pump		$632,000
2000 ft pipe, elbows, valves		51,000
2 1,000-gal storage tanks		6,000
1 200-gal storage tank		2,000
Subtotal		$691,000
Contingencies, engineering, electrical, installation, 42%		$291,000
Total		$982,000
Savings		$/yr
Recoverable dye, 130 lb/yr		$ 400
Water and sewer, 6.0 x 10^6 gal/yr		9,000
Total	approx.	$ 9,400
O&M Costs		119,000
Net Annual Costs		$110,000

No payback

- Continuous dye range operates 100 days per year.
- Assumed 10 percent blowdown required for permeate and concentrate.

Capital and annual costs are based on a 66,000-gpd design flow, without regard for other important parameters such as flux rate, and dyehouse operation times. Therefore, these costs are possibly conservative, as indicated by the fact that a similar system at LaFrance had capital costs of about $500,000.

Annual costs exceed the annual savings under the assumptions stated above. Under these assumptions, therefore, no payback is expected. With greater chemical recovery that may occur with greater production, or at greater amounts of dye and chemicals in the rinse water, the potential for net annual savings increases. Actual chemical savings would need to be carefully studied in pilot tests.

ENVIRONMENTAL BENEFITS

The use of this recycle technology results in a reduction in wastewater flow of about 6 million gallons/year, or 60,000 gpd when the continuous dye range is operating.

The hyperfiltration system is expected to reduce discharge of organics and color, but the extent of these reductions depends on the actual amounts of dyes and auxiliary chemicals recovered. Table V-1 indicates that the rinse water is fairly dilute with respect to pollutant parameters, so that overall reductions are not expected to be significant.

CONCLUSIONS

- Pilot testing is needed to confirm the technical feasibility of hyperfiltration for dye recovery, and to establish design criteria for the recycle system.
- Actual chemical savings must be examined during pilot tests to more carefully determine economic feasibility. Preliminary analysis shows the economics are not promising.
- Environmental benefits of hyperfiltration of dye wastewater for dye recovery are expected to be minor.

MILL SURVEY REPORT
MILL Y-4
ACRYLIC YARN DYEING

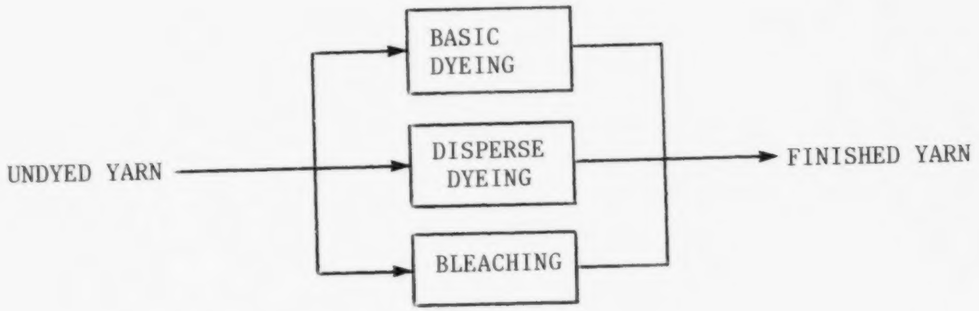
SUMMARY

Mill Y-4 is a yarn dyeing facility. Basic and disperse dyeing of acrylic yarn, as well as bleaching, are the principal manufacturing operations here. Water use approaches and sometimes exceeds 1 mgd. Figure 1 presents the basic manufacturing processes and recycle/reuse options considered, and summarizes both technical and economic feasibility as well as further research needs for each alternative. Table 1 illustrates the projected savings, costs, and paybacks associated with recycle/reuse options considered at this mill.

Two recycle/reuse technologies were considered at this mill: dyebath reconstitution, and chlorine oxidation (decoloring) and recycle of dyeing wastewater.

Reconstitution of basic dye, disperse dye, and bleach bath wastewaters is both economically and technically attractive at Mill Y-4. Reconstitution should be pursued and implemented further.

Basic dyebath reconstitution is a demonstrated technology at this mill. As a result there is little impetus to further pursue the much more expensive recycle technology of dyebath decoloring by chlorine oxidation.


UNDYED YARN
BASIC DYEING
DISPERSE DYEING
BLEACHING
FINISHED YARN

Technologies Evaluated	Feasibility Technical	 Economic	Data Needs
Basic Dyeing			
Decolorization (Cl_2) and reuse	Marginal	Marginal	Additional testing
Direct Reuse (Reconstitution)	Feasible*	Promising	None*
Disperse Dyeing			
Direct Reuse (Reconstitution)	Feasible	Marginal	Demonstration
Bleaching			
Direct Reuse (Reconstitution)	Feasible*	Promising	None*

* Has already been demonstrated at mill on full-scale

FIGURE 1. MANUFACTURING PROCESSES AND POTENTIAL RECYCLE/REUSE TECHNOLOGIES AT MILL Y-4.

TABLE 1

SUMMARY OF ECONOMIC AND ENVIRONMENTAL BENEFITS OF RECYCLE/REUSE OPTIONS

Recycle/Reuse Scheme	Net Annual Savings	Capital Cost	Payback (years)	Flow Reduction		COD Reduction	
				gpd	% Total	lb/day	% Total
Chlorine Oxidation of Basic Dye Wastewater	$141,000	$355,000	2.5	175,000	20	875	40
Reconstitution of Basic Dye Wastewater* (holding tank)	38,000	12,000	0.3	7,560	1	48	2.4
Reconstitution of Disperse Dye Wastewater* (rinse tank)	2,900	9,500	3.3	7,560	1	**	**
Reconstitution of Bleach Bath Wastewater* (holding tank)	25,000	12,000	0.5	8,500	1	8	0.4

* Per Machine

** Insufficient Information

TABLE OF CONTENTS

Page

Summary ii
Table of Contents. v

I. INTRODUCTION 1
  Facility Description 1
  Manufacturing Processes 1
  Overall Mass and Energy Balances 4
  Evaluation of Recycle/Reuse Technologies 13

II. CHLORINE OXIDATION OF BASIC DYE WASTEWATER 14
  Description of Manufacturing Process and Proposed Modification 14
  Technical Feasibility and Design Criteria 14
  Economic Feasibility 21
  Environmental Benefits 24
  Conclusions 24

III. ALTERNATIVE RECONSTITUTION METHODS 26
  Description of Manufacturing Process and Proposed Modification 26
  Technical Feasibility and Design Criteria 27
  Economic Feasibility. 28
  Environmental Benefits 31
  Conclusions 31

IV. RECONSTITUTION OF BASIC DYEBATHS 32
  Description of Manufacturing Process and Proposed Modification 32
  Technical Feasibility and Design Criteria 32

TABLE OF CONTENTS (continued)

Page

Economic Feasibility 36
Environmental Benefits 38
Conclusions 38

V. RECONSTITUTION OF DISPERSE DYEBATHS 40
Description of Manufacturing Process and Proposed Modification 40
Technical Feasibility and Design Criteria 40
Economic Feasibility 44
Environmental Benefits 46
Conclusions 46

VI. RECONSTITUTION OF BLEACH BATHS 49
Description of Manufacturing Process and Proposed Modification 49
Technical Feasibility and Design Criteria 49
Economic Feasibility 51
Environmental Benefits 53
Conclusions 53

References 57

SECTION I
INTRODUCTION

Mill Y-4 is a major yarn dyeing facility located in the Southeast. This report assesses the applicability of two technologies, chlorine decolorization and reconstitution, to enable reuse of the process wastewater from this facility.

FACILITY DESCRIPTION

This mill is primarily engaged in the dyeing of acrylic yarn, with over 95 percent of the finishing on a weight basis being comprised of this activity. A flow schematic of the yarn dyeing operations is presented in Figure I-1. Of the total finished acrylic yarn production, 68 percent is basic dyed, 22 percent is disperse dyed, and 10 percent is bleached white. The remaining finishing activities at this mill are varied, but insignificant in terms of total production.

MANUFACTURING PROCESSES

Yarn Dyeing

There are over 20 dye machines in the yarn dyeing area, all but four of which are pressure machines. All the machines are operated almost constantly six days per week. Bleaching, basic dyeing, and disperse dyeing are performed in the pressure machines. The atmospheric machines are used for shaded and variegated shade dyeing. A substantial number of repeat operations occur in the yarn dyeing area.

Basic dyeing comprises the majority of dyeing at Mill Y-4. This dye class is used for dyeing acrylic yarn and exhausts to about 95 percent. A schematic of the basic dyeing process at this mill is presented in Figure I-2. The dye machine is filled with warm water and sodium sulfate is added. The pH is depressed to the range 3 to 5 with sulfuric or acetic acid. Next added are a leveler/retarder, softener, and non-ionic wetter. Basic dyes are added and the dyebath temperature raised for dyeing. After the goods have been dyed, the bath is cooled and dumped, and the goods are rinsed with fresh water. This cycle requires about 4-1/2 hours.

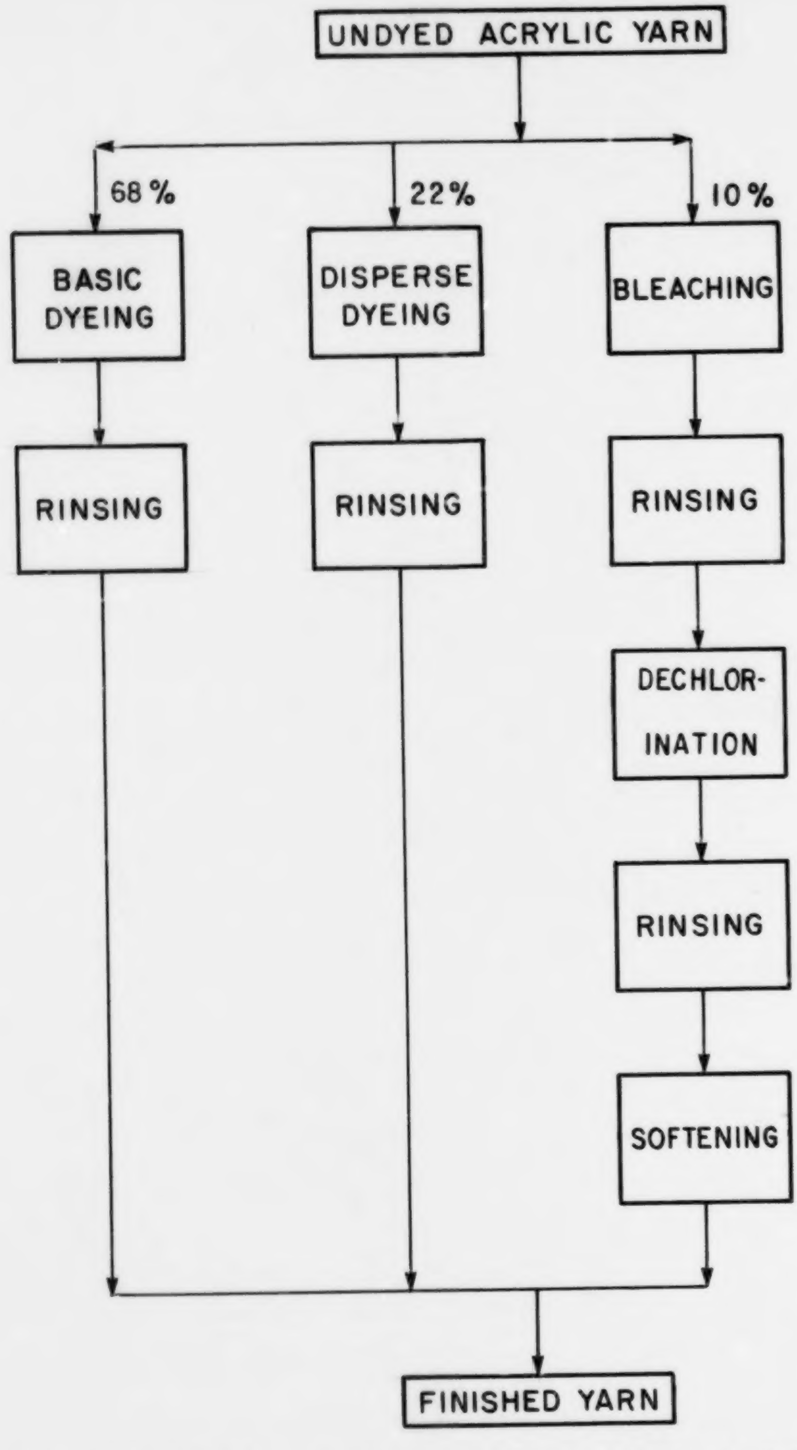

UNDYED ACRYLIC YARN
68 %
22 %
10 %
BASIC DYEING
DISPERSE DYEING
BLEACHING
RINSING
RINSING
RINSING
DECHLOR-INATION
RINSING
SOFTENING
FINISHED YARN

FIGURE I-1 GENERAL ACRYLIC YARN DYEING ACTIVITIES AT MILL Y-4

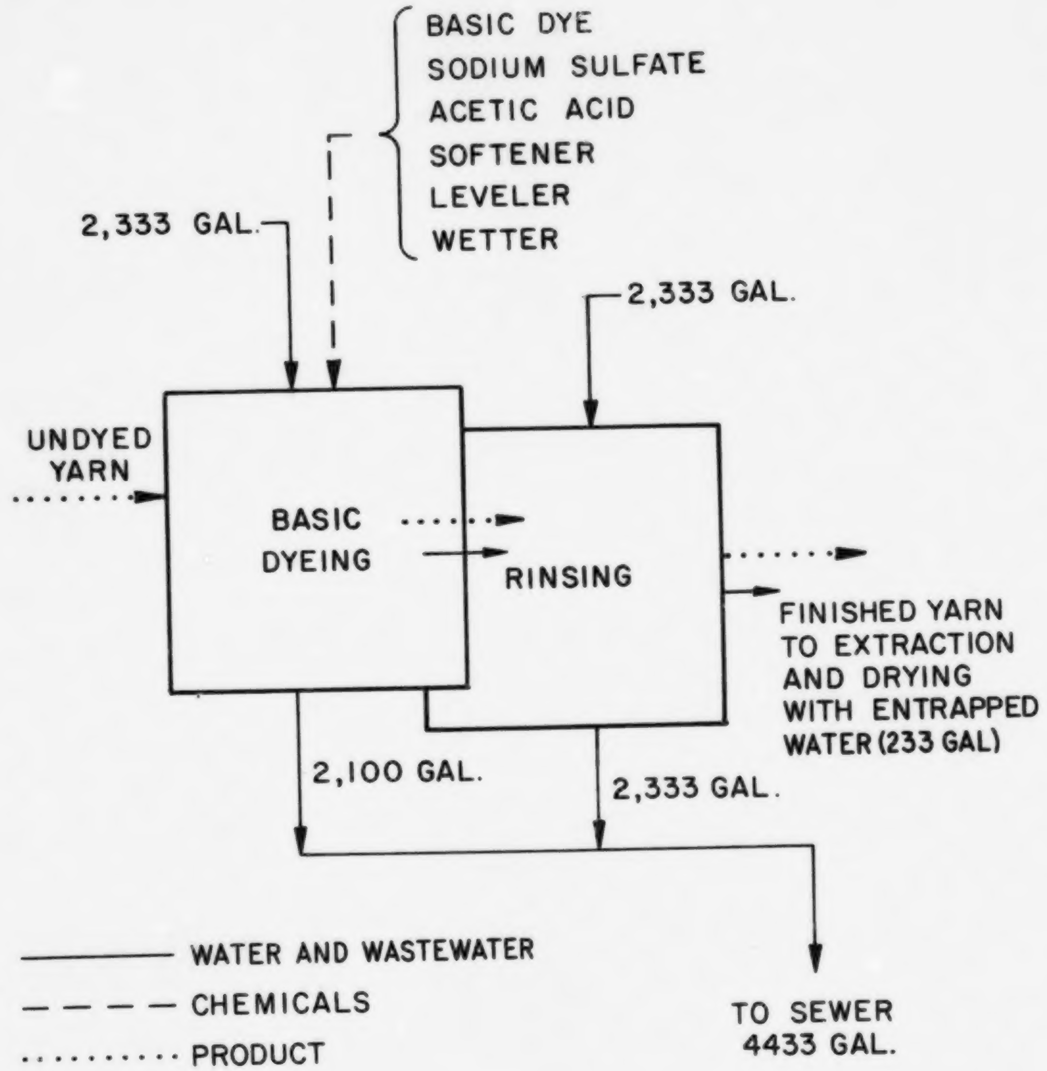

BASIC DYE
SODIUM SULFATE
ACETIC ACID
SOFTENER
LEVELER
WETTER
2,333 GAL.
2,333 GAL.
UNDYED YARN
BASIC DYEING
RINSING
FINISHED YARN TO EXTRACTION AND DRYING WITH ENTRAPPED WATER (233 GAL)
2,100 GAL.
2,333 GAL.
WATER AND WASTEWATER
CHEMICALS
PRODUCT
TO SEWER 4433 GAL.

FIGURE I-2 FLOWS ASSOCIATED WITH BASIC DYEING (PER 1000LB PRODUCTION)

Disperse dyeing is also used to dye some acrylic fibers. This process is illustrated in Figure I-3. The dye machine is filled with warm water, and non-ionic wetter and disperse dyes are added. The dyebath is heated and the goods are dyed. The bath is then cooled and dropped. The machine is then filled with fresh water for rinsing, and both softener and acetic acid are added. After rinsing, the bath is dumped. The total disperse dyeing cycle lasts about two hours.

Yarn is bleached by filling the machine with warm water and adding sodium chlorite and auxiliary chemicals. The bath is then heated and subsequently cooled and dropped. Steps for dechlorination, softening, and rinsing follow. The bleaching cycle usually takes about 3-1/2 hours to complete and is shown in Figure I-4.

Other Finishing

Miscellaneous other fibers and products are dyed and finished at this facility. Although this dyeing and finishing accounts for only a small portion (five percent) of the total production at Mill Y-4, numerically over 40 percent of the dyeing machines at the mill are available for these various activities. Four-fifths of these are package dyeing machines of various sizes and they are used to perform pressure dyeing. The remainder are skein dyeing machines used to perform atmospheric dyeing.

OVERALL MASS AND ENERGY BALANCES

Water and Wastewater and Characteristics

Mill Y-4 purchases city water and softens it prior to use. The characteristics of this softened city water are presented in Table I-1.

Water use at Mill Y-4 during the sampling period, based on flow readings of softened water, averaged 1.09 mgd for a 6-day work week. This is significantly higher than would be expected based on other factors. For example, based on operating 300 days per year, the average daily flow calculated from water use billings in 1981 was 0.76

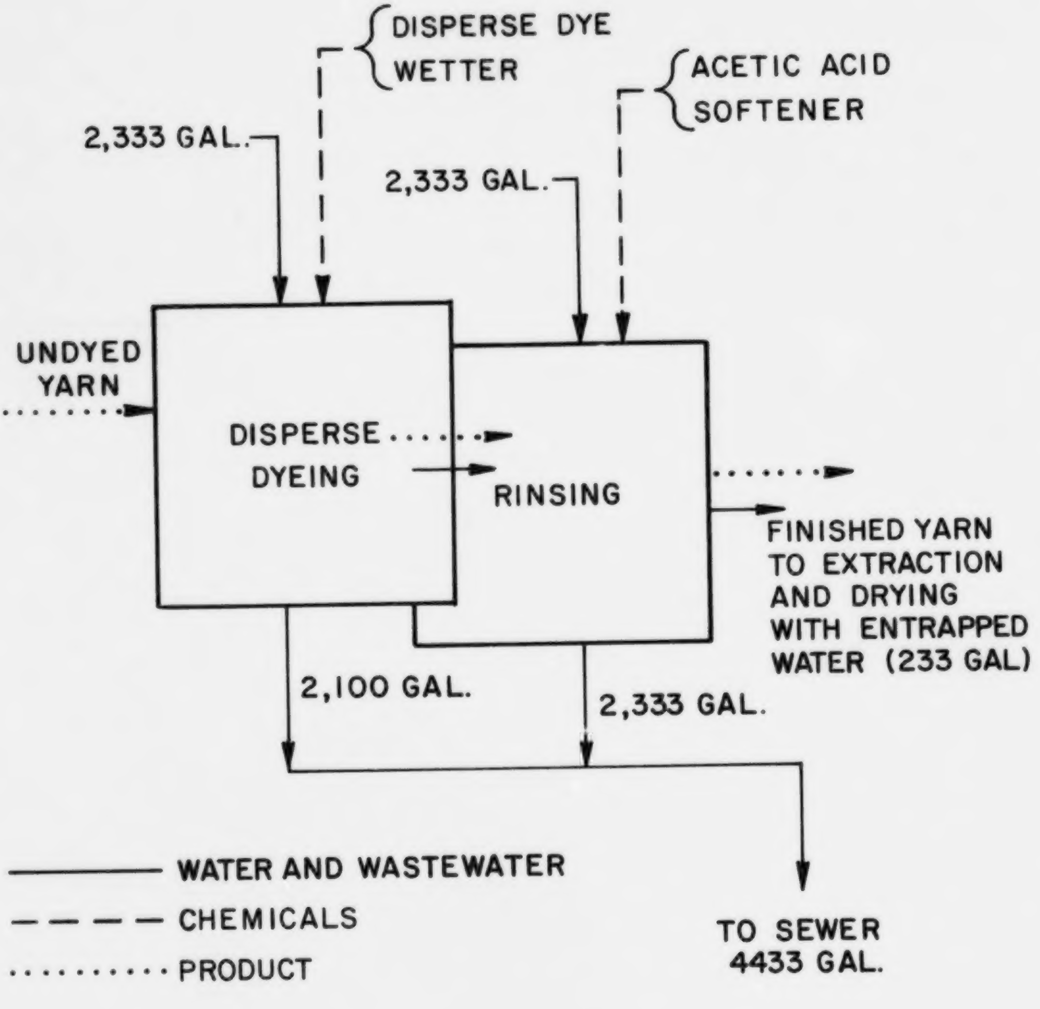
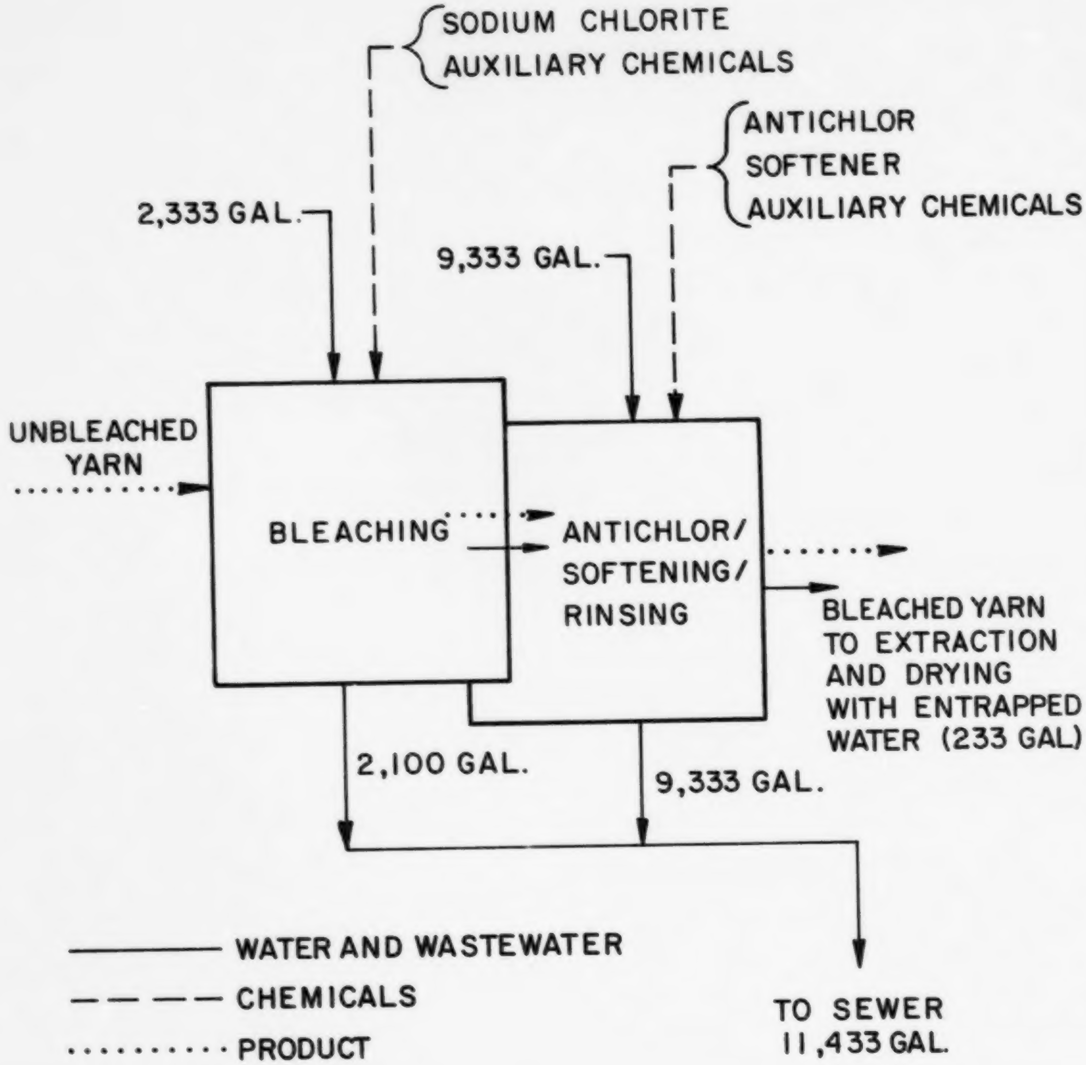

DISPERSE DYE
WETTER
ACETIC ACID
SOFTENER
2,333 GAL.
2,333 GAL.
UNDYED YARN
DISPERSE DYEING
RINSING
FINISHED YARN TO EXTRACTION AND DRYING WITH ENTRAPPED WATER (233 GAL)
2,100 GAL.
2,333 GAL.
WATER AND WASTEWATER
CHEMICALS
PRODUCT
TO SEWER 4433 GAL.

FIGURE I-3 FLOWS ASSOCIATED WITH DISPERSE DYEING (PER 1000LB PRODUCTION)



SODIUM CHLORITE
AUXILIARY CHEMICALS
ANTICHLOR
SOFTENER
AUXILIARY CHEMICALS
2,333 GAL.
9,333 GAL.
UNBLEACHED YARN
BLEACHING
ANTICHLOR/ SOFTENING/ RINSING
BLEACHED YARN TO EXTRACTION AND DRYING WITH ENTRAPPED WATER (233 GAL)
2,100 GAL.
9,333 GAL.
WATER AND WASTEWATER
CHEMICALS
PRODUCT
TO SEWER 11,433 GAL.

FIGURE I-4 FLOWS ASSOCIATED WITH BLEACHING (PER 1000LB PRODUCTION)

TABLE I-1
WATER QUALITY FOR SOURCE WATER

Parameter	Concentration (mg/l)*
pH	7.3
Temperature [°F (°C)]	75 (24)
Color (ADMI)	13
BOD	15
COD	31
TS	190
TDS	230
TSS	0
Phenolics	< 0.04
Chloride	11
Alkalinity	137
Hardness	< 1
Cadmium	< 0.1
Chromium	< 0.1
Copper	< 0.1
Iron	0.1
Nickel	< 0.1
Sodium	89
Zinc	0.24

* Sampled on April 29, 1982

mgd. Although yarn dyeing activities were fairly typical during the field investigation, the output due to other dyeing activities during the sampling period was almost double the average weekly 1981 production figure for these activities. These activities may have accounted for the higher water use.

Dyehouse wastes pass through a Ludell heat exchange system to recover some of the heat present in discharged wastewater. After passing through the heat recovery system and a lint screen, the wastewater flows into a settling pond before being discharged to the municipal sewer. This basin provides a 1 to 1.5 day detention period and is located about 1/3 mile from the plant. Pollutant concentrations found in the final (pond) effluent are presented in Table I-2.

In addition to source water and effluent discharge, wastewater samples from dye machines performing basic dyeing, disperse dyeing, and bleaching operations were also collected and analyzed. Conventional and nonconventional pollutant concentrations for various dye and bleach baths, as well as the final effluent are shown in Table I-3. Daily mass loadings of these pollutants are listed in Table I-4. Other wastewater constituents that affect recycle are discussed in subsequent sections of this report under the appropriate recycle technologies.

According to Table I-4, virtually all of the BOD and COD are attributable to yarn dyeing operations here, yet only about a tenth of suspended solids are generated in these operations. It is possible that biological activity in the settling pond or contamination from dusty fields and roads nearby contributed to the suspended solids level in the final effluent.

Energy

Energy requirements at Mill Y-4 are met using natural gas, fuel oil, and electricity. The present boiler, providing steam for heating the dye machines and other needs, uses natural gas or fuel oil depending on the season. It will soon be replaced with a coal-fired boiler. In 1981, natural gas usage was 158,883 MCF and fuel oil usage was 913,835 gallons. Electricity is used for machinery operation and lighting, and 5,330,368 kwh were consumed in 1981. A Ludell heat recovery system is used at this facility to recovery some of the heat present in discharged wastewater.

TABLE I-2

FINAL EFFLUENT CHARACTERIZATION

Parameter	Average Concentration (mg/l)*	
pH (median)	7.3	
Temperature [°F (°C)]	97	(36)
Color (ADMI)	250	
BOD	85	
COD	290	
TS	1590	
TDS	1490	
TSS	47	
Phenolics	< 0.047	(2 samples)
Hardness	85	
Cadmium	**	
Copper	< 0.11	
Iron	0.24	
Nickel	**	
Zinc	0.56	

---

* Based on 3 24-hour automatic composite samples from April 29, 30, and May 1, 1982.

** Below analytical quantification level

TABLE I-3
WASTEWATER CHARACTERISTICS

Wastewater Source	Batch or Date	Concentrations (mg/l)				
		BOD_5	COD	TSS	Phenolics	pH
Basic Dyeing Bath	1	100	610	16	< .040	4.4
	2	150	1,200	30	< .040	4.4
	3	300	1,100	19	< .040	4.5
	4	1,300	2,800	35	< .040	4.5
	5	540	610	32	< .040	4.4
	6	80	790	30	< .040	6.6
	Average	410	1,180	27	< .040	--
Basic Dyeing Rinse	1	110	360	13	< .040	7.0
	2	130	540	28	< .040	7.4
	3	92	320	51	< .040	6.7
	4	56	310	4	< .040	7.4
	5	140	1,340	8	< .040	6.8
	6	84	--	40	--	7.5
	Average	100	570	24	< .040	--
Disperse Dyeing Bath	1	220	1,000	2	.062	8.3
	2	350	1,500	3	.051	6.8
	3	310	1,230	< 1	< .040	8.1
	Average	290	1,240	2	< .051	--
Disperse Dyeing Rinse	1	72	290	6	< .040	6.7
	2	100	280	7	< .040	6.2
	3	96	290	8	< .040	6.3
	Average	89	290	7	< .040	--

TABLE I-3 (Cont'd)

Wastewater Source	Batch or Date	Concentrations (mg/l)				
		BOD_5	COD	TSS	Phenolics	pH
Bleach Bath	1	380	840	< 1	< .040	3.6
	2	260	870	6	< .040	3.5
	Average	320	855	< 4	< .040	--
Bleach Rinse	1	37	170	< 1	< .040	6.5
	2	35	130	6	< .040	6.1
	Average	36	150	< 4	< .040	--
Bleach Dechlorination Bath	1	22	--	5	--	--
	2	23	140	6	< .040	6.0
	Average	22	140	6	< .040	--
Bleach Dechlorination Rinse	1	--	--	--	--	--
	2	12	94	6	< .040	6.3
	Average	12	94	6	< .040	--
Bleach Softening Bath	1	19	100	15	< .040	6.4
	2	18	78	2	--	5.3
	Average	18	89	8	< .040	--
Final Effluent	4/29/82	68	280	15	.054	7.3
	4/30/82	140	310	26	< .040	7.3
	5/1/82	48	270	100	--	5.9
	Average	85	290	47	< .047	--

TABLE I-4
POLLUTANT LOADINGS

Wastewater Source	Flow		BOD_5		COD		TSS		Phenolics	
	gal/day	% Total	lb/day	% Total	lb/day	% Total	lb/day	% Total	lb/day	% Total
Basic Dyeing Bath	96,782	12	331	57	952	48	22	7	< .032	10
Basic Dyeing Rinse	96,782	12	81	14	460	23	19	6	< .032	10
Disperse Dyeing Bath	32,263	4	78	13	334	17	< 1	< 1	< .013	4
Disperse Dyeing Rinse	32,263	4	24	4	78	4	2	< 1	< .011	3
Bleach Bath	13,195	2	35	6	94	5	< 1	< 1	< .004	1
Bleach Rinse	13,195	2	4	1	17	1	< 1	< 1	< .004	1
Bleach Dechlorination Bath	13,195	2	2	< 1	15	1	< 1	< 1	< .004	1
Bleach Dechlorination Rinse	13,195	2	1	< 1	10	1	< 1	< 1	< .004	1
Bleach Softening Bath	13,195	2	2	< 1	10	1	< 1	< 1	< .004	1
Other Flows*	500,935	--	27	--	30	--	270	--	< .323	--
Final Effluent	825,000**	100	585	100	2,000	100	320	100	< .323	100

* Miscellaneous streams such as flows from other finishing activities, machine washing in yarn dyeing area, sanitary, cooling, utility, and other plant flows. Flow and loadings attributed to this classification represent the difference between measurements of the final effluent and measurements of the basic dyeing, disperse dyeing, and bleaching operations.

**Based on water use minus estimated product losses, evaporation, and steam losses.

EVALUATION OF RECYCLE/REUSE TECHNOLOGIES

The recycle/reuse technologies applicable to Mill Y-4 that are evaluated in this report are the following:

1. Basic dye wastewater - chlorine oxidation for decolorization.
2. Alternative reconstitution methods - holding tanks; in situ reconstitution with separate rinse tanks.
3. Reconstitution of exhausted basic dyebaths.
4. Reconstitution of exhausted disperse dyebaths.
5. Reconstitution of exhausted bleach baths.

SECTION II

CHLORINE OXIDATION OF BASIC DYE WASTEWATER

DESCRIPTION OF MANUFACTURING PROCESS AND PROPOSED MODIFICATION

Dyeing is performed 6 days a week at Mill Y-4. In a typical week, approximately 277 batches of yarn would be basic dyed. Wastewater due to basic dyeing, including rinsing, during this period would be 1.16 million gallons. Typical daily figures would be as follows: 46 batches and 193,000 gpd. A schematic of the flows, production, and chemicals associated with a typical batch was illustrated in Figure I-2. It is estimated that approximately 57 percent of the wastewater from yarn dyeing is associated with basic dyeing. Table II-1 presents the wastewater characteristics associated with these flows.

A comparison of the existing and revised process schematic incorporating chlorine oxidation is shown in Figure II-1. Scheduling and piping modifications will be necessary in order to segregate the basic dye wastewater from other mill wastewaters. An equalization tank is necessary prior to the chlorine oxidation system to enable blending of the wastewater and thus prevent sudden changes in the wastewater being treated. The wastewater next enters a series of treatment tanks in which it is decolored by chlorine oxidation. Liquid caustic is used as a buffer to maintain proper pH during oxidation, and sulfur dioxide gas is employed as an antichlor. Decolored water is filtered to remove larger particulates and is stored briefly before being returned to the dyehouse for reuse in basic dyeing. It is important that the water returned to the mill be segregated and used only for basic dyeing to prevent problems with other activities such as bleaching and disperse dyeing.

TECHNICAL FEASIBILITY AND DESIGN CRITERIA

Literature and Previous Applications

Both Perkins, et al. (Reference 1), and Textile Systems, Inc. (TSI) have investigated decolorization of various dye wastewaters by chemical oxidation. Ozone and chlorine have both been successful with

TABLE II-1

BASIC DYE WASTEWATER CHARACTERIZATION

Parameter	Average Concentration (mg/l)* Dyebath	 Rinsewater
pH (median)	4.4	7.2
Temperature [°F(°C)]	209 (98)	99 (37)
BOD	410	100
COD	1,180	570 (5 samples)
TS	9,500	840
TDS	9,180	710
TSS	27	24
Hardness (as $CaCO_3$)	43**	1
Phenolics	$<$ 0.040	$<$ 0.040 (5 samples)
Color (ADMI)	14,430***	150

Selected metals were also analyzed in the wastewater from one basic dyebath sample and the results were as follows: Cd - $<$0.1 mg/l; Cr - $<$0.1 mg/l; Cu - $<$0.1 mg/l; Fe - 0.2 mg/l; Ni - 0.1 mg/l; Zn - 1.8 mg/l

*Based on 6 grab samples unless otherwise noted

**One value was 240. Without this value, the average is 4.

***One value was 83,000. Without this value, the average is 710.

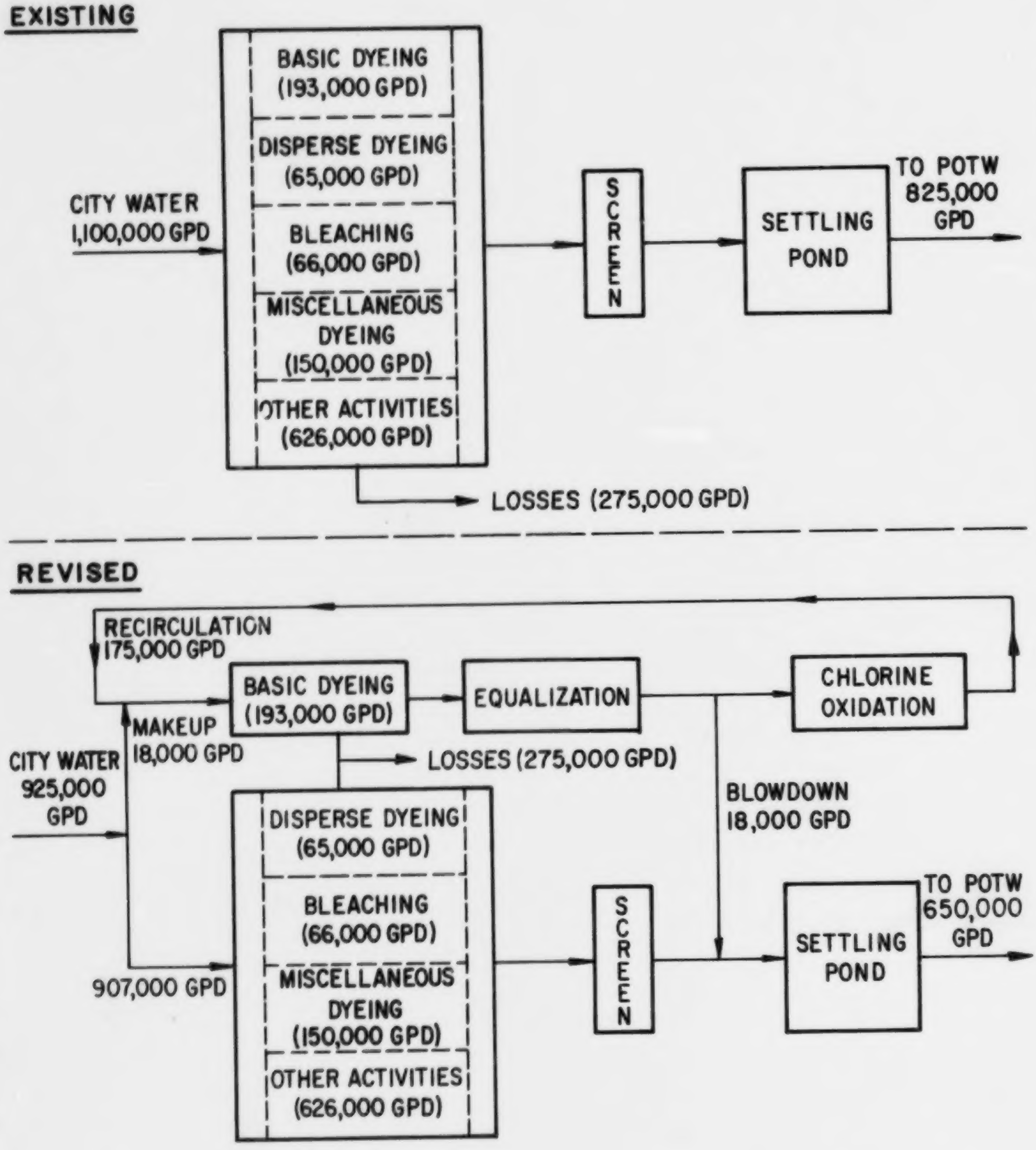

EXISTING
CITY WATER 1,100,000 GPD
BASIC DYEING (193,000 GPD)
DISPERSE DYEING (65,000 GPD)
BLEACHING (66,000 GPD)
MISCELLANEOUS DYEING (150,000 GPD)
OTHER ACTIVITIES (626,000 GPD)
SCREEN
SETTLING POND
TO POTW 825,000 GPD
LOSSES (275,000 GPD)
REVISED
RECIRCULATION 175,000 GPD
BASIC DYEING (193,000 GPD)
EQUALIZATION
CHLORINE OXIDATION
MAKEUP 18,000 GPD
CITY WATER 925,000 GPD
LOSSES (275,000 GPD)
BLOWDOWN 18,000 GPD
DISPERSE DYEING (65,000 GPD)
BLEACHING (66,000 GPD)
MISCELLANEOUS DYEING (150,000 GPD)
OTHER ACTIVITIES (626,000 GPD)
907,000 GPD
SCREEN
SETTLING POND
TO POTW 650,000 GPD

FIGURE II-1. COMPARISON OF EXISTING AND REVISED DYEHOUSE WASTEWATER TREATMENT SYSTEMS EMPLOYING CHLORINE OXIDATION.

certain dyes in producing a water suitable for reuse in dyeing, and test dyeings over a series of reuse applications have been acceptable.

Oxidation has been shown to decrease the molecular weight of dye molecules by attacking amide and other molecular linkages, thereby destroying chromophoric groups and decoloring the wastewater.

Thus far, only oxidation by chlorine has been employed in full-scale applications for dye wastewater decolorization, and this has been primarily for acid dyes. Ozone has not been applied because of costs of generation, practicality, and safety hazards.

Research by Perkins considered only acid, direct, disperse, and reactive dyes. Of dye classes that TSI has had experience with, basic dye wastewaters are more expensive to treat than acid or disperse dye wastewaters, but cost somewhat less to treat than fiber reactive dye wastewaters. In general, TSI's attitude is that although most dyes are treatable with their system, acid and disperse dyes are most appropriate for treatment by chlorine oxidation due to complications associated with treatment of other dyestuffs.

Bench Scale Results

Bench scale chlorine decolorization tests were performed on three basic dye wastewater samples. Each sample was comprised of 4 exhausted basic dyebaths combined in equal portions. The samples were dosed at three levels: approximately 25, 50, and 100 mg/l of chlorine. A dilute solution of commercial bleach was standardized and added in varying amounts to each aliquot of waste. A common dilution factor of 5 percent was obtained by adding chlorine demand-free dilution water to compensate for the varying volumes of chlorine solution needed. Samples were placed in a darkened area immediately after dosing for 15 minutes. Optimum dosage for decolorization was determined visually and noted for additional testing. Aliquots were then taken from all samples for total, free, and available chlorine analyses and the remaining samples were dechlorinated with an excess of solid sodium thiosulfate. ADMI color was run on all dechlorinated samples. In addition, milliliters titrant to pH 7, total dissolved solids, and turbidity were run on those samples previously selected as being the most decolored. The characteristics of these wastewater samples prior to treatment are shown in Table II-2. Pertinent information concerning the treated samples is presented in Table II-3.

As can be seen from Table II-3, color levels decreased significantly as chlorine dosages increased with samples A and C. Sample B was relatively color free to start, and treatment had little effect. And in all three samples, turbidity and total dissolved solids levels increased somewhat following treatment.

These bench scale tests show that the basic dye wastewater is readily decolored by chlorine but that a dose of 100 mg/l is generally required. A 10- to 15-minute reaction time appears sufficient.

Technical Design Criteria

TSI has a patent covering the decolorization of textile dye wastes by chlorination. The smallest standard TSI treatment unit employing this technology is sized at 175 gpm (250,000 gpd). However, the relevant flow at Mill Y-4 is only 175,000 gpd. A 250,000 gpd unit provides a hydraulic safety factor of 1.4.

The information developed in the aforementioned bench scale trials indicate a chlorine dose of 100 mg/l to be necessary for decolorization of basic dye wastewaters. However, the wastewater in these experiments was dye wastewater only. Fifty percent of the flow to the full-scale decolorization system would be comprised of "colorless" rinse water. Hence a design chlorine dosage of 50 mg/l should be sufficient for the combined dye and rinse waters.

A holding tank providing 10,000 gallons storage (approximately one hour) prior to the treatment system is necessary. Storage capacity for return to the mill is equal to the volume anticipated in two hours of average flow, i.e., 15,000 gallons.

Design criteria are summarized in Table II-4.

The discussions in this section assume that dyebath reconstitution is not practiced at the mill. It is impractical for a mill that reconstitutes a significant fraction of its dyebaths to institute chlorine oxidation since the primary economic impetus for both

TABLE II-2
BENCH-SCALE CHLORINE DECOLORIZATION STUDY - UNTREATED SAMPLE CHARACTERIZATION

Parameter	Concentration (mg/l) Sample A*	Sample B*	Sample C*
pH	3.8	3.9	6.0
Turbidity	< 1	< 1	< 1
BOD	NA	340	1,090
COD	1,470	340	1,500
TS	9,895	8,600	9,030
TDS	6,140	8,420	8,520
TSS	3	15	11
Hardness (as $CaCO_3$)	48	8.1	< 1
Phenolics	< 0.040	< 0.040	< 0.040
Color (ADMI)	26,000	357	17,200
Alkalinity (as $CaCO_3$)	0	0	0
Chloride	694	41	120
Total Phosphorus (as P)	NA	NA	1.2
Sodium	4,100	3,900	NA

*Samples are each comprised of 4 exhausted basic dyebaths combined in equal portions

NA - No Analysis

TABLE II-3

BENCH-SCALE CHLORINE DECOLORIZATION STUDY

TREATED SAMPLE CHARACTERIZATION

Sample	Chlorine Dosage (mg/l)	Chlorine Remaining After 15 minutes (mg/l)	Chlorine Consumed (mg/l)	ADMI Color* Original pH	ADMI Color* Final pH = 7.6	Acid to** Adjust to pH = 7 (ml/25 ml dosed sample)	Total Dissolved Solids (mg/l)	Turbidity (NTU)	Comments
Sample A	110	20	89	640	700	0.35	9900	10	Very red sample-color masked Cl_2 DPD endpoint
	54	See Comment	--	7,700	5,900	--	--	--	
	27	See Comment	--	14,000	11,000	--	--	--	
	0	--	--	25,000	26,000	--	6140	< 1	
Sample B	110	42	67	220	230	0.35	9000	13	Distinct color change from green to yellow
	54	10	45	490	460	--	--	--	
	27	11	16	440	900	--	--	--	
	0	--	--	361	357	--	8420	< 1	
Sample C	110	39	70	310	410	1.1	9400	89	Orange sample which turned red - color masked Cl_2 DPD endpoint
	54	See Comment	--	980	1,300	--	--	--	
	27	See Comment	--	6,200	5,400	--	--	--	
	0	--	--	34,100	17,200	--	8520	< 1	

---

*Values for dosed samples not corrected for 5% dilution factor.
**0.025N Sodium hydroxide (NaOH).

wastewater recycle/reuse schemes is auxiliary chemical recovery. In addition, reconstitution leads to lower flows and may cause the buildup of certain interfering substances that could affect the chlorine dosage and reaction time needed for decoloring.

ECONOMIC FEASIBILITY

Cost savings are realized in the areas of water use, wastewater discharge, energy savings, and auxiliary chemical use. In addition to capital costs for the treatment system, additional operating costs will be encountered both for labor and chemicals for the oxidation/recycle process.

Table II-5 presents an analysis of the annual cost savings realized through dyebath oxidation and recycle. The basis of these costs and savings is as follows:

- average daily flow due to basic dyeing is 193,000 gpd, evenly divided between dye wastewater and rinse wastewater
- blowdown from system is 10 percent
- plant operates 300 days per year
- treatment chemical requirements are as given in Table 2-4
- treatment chemical costs:
    - chlorine at \$0.08/lb
    - caustic at \$0.27/lb
    - sulfur dioxide at \$0.15/lb
- annual labor requirement is 4 man years
- cost of water supply is 24.63¢/1,000 gallons
- cost of wastewater discharge is 58.90¢/1,000 gallons
- forty percent recovery of leveler, sodium sulfate, and wetter chemicals used in basic dyeing; six percent recovery of softener
- mill pays \$5.64/million Btu
- source water available at 90°F; return from chlorine decolorization storage tanks at 120°F.

The estimated capital cost (June, 1982) of an oxidation recycle system for this mill is approximately \$350,000, including cost for the reaction and storage tanks, chemical feed and control systems,

TABLE II-4
DESIGN CRITERIA
DYEBATH OXIDATION/RECYCLE

Oxidation		
Reaction Time	minutes	10
Chlorine Dose	mg/l	50
	lb/day	75
Reaction pH		
Caustic Feed	mg/l	90
	lb/day	130
Dechlorination		
Reaction Time	minutes	5
Sulfur Dioxide Dose	mg/l	50
	lb/day	75
Total Treatment Capacity	gallons	10,000
	hours at average flow	1.4
Storage Capacity	gallons	15,000
	hours at average flow	2
Hydraulic		
Flow (average)	gpm	120
	mgd	0.175
Design Flow	gpm	175

TABLE II-5
ECONOMICS
DYEBATH OXIDATION

Annual Operating Costs

Oxidation Process Chemicals		$ 16,000
Oxidation Process Labor		80,000
Oxidation Process Maintenance		20,000
	Total	$116,000

Annual Savings

Water Supply		$ 13,000
Sewer Use Charges		31,000
Auxiliary Chemicals		138,000
Energy (Steam Savings)		75,000
	Total	$257,000

Capital Cost

Equalization and Chlorine Oxidation	$355,000

Payback

Payback is estimated at approximately 2.5 years.

piping, pumps, electrical service, site work, and engineering costs. The resulting payback period is about 2.5 years based on annual operating savings of approximately $140,000. However, the payback period is sensitive to projected chemical savings. For example, if only 50 percent of the chemical savings projected above were realized, the payback period would nearly double to 5 years.

In addition, the mill has identified a number of other factors that could affect the economics or practicality of chlorine oxidation here. Among the items that would need to be examined prior to implementation of a chlorine decolorization system are the following:

- potential oxidation of retarder-levelers, resulting in lower chemical savings
- possibility that exhaustion curves and retarders would be altered resulting in dyeing problems for particular shades
- ability to control softener amounts when using reuse water for dyeing

Although potential problems such as these may be solvable, the costs of overcoming or minimizing these problems may result in a significantly longer payback period than that projected in Table II-5.

ENVIRONMENTAL BENEFITS

The recirculation of 175,000 gpd as a result of chlorine oxidation would reduce the mill's yarn dyeing wastewater discharge by 54 percent; total mill discharge would be reduced by 20 percent. Total mill BOD_5 and COD discharge amounts would be reduced by about 40 percent, or by 250 lb/day and 875 lb/day respectively. Energy savings of approximately 44 million Btu per day would be realized.

CONCLUSIONS

- The economics of chlorine oxidation at this mill appear marginal due to high capital costs.
- Additional testing is necessary to determine optimal dosages, percent of auxiliary chemical recovery, and the effect on product quality of reusing the decolorized water for dyeing and rinsing.

- Potential formation of chlorinated organics as a result of treatment needs to be studied. The mill feels chlorinated aromatics are likely due to the levelers and softener used in dyeing.

SECTION III

ALTERNATIVE RECONSTITUTION METHODS

DESCRIPTION OF MANUFACTURING PROCESS AND PROPOSED MODIFICATION

The batch dyeing process, both at this and other textile mills, generally consists of the following procedures. Source water and the product to be dyed are first added to the dyeing vessel. Dyes and auxiliary chemicals, such as pH control agents, leveling agents, softening agents, and wetting agents, are next added. The dyebath is then slowly heated to the appropriate dye strike temperature, and this temperature is maintained for the appropriate dyeing period. Upon completion of dyeing, the bath is cooled and dumped. This exhausted dyebath, although devoid of most of the original dyestuffs, still contains nearly all of the auxiliary chemicals, as these are theoretically unchanged by the dyeing process and do not generally exhaust onto the product.

Dyebath reconstitution is a modification to this traditional dyeing process wherein the spent dyebath following each dyeing cycle is analyzed, reconstituted to the desired concentration of dyes and auxiliary chemicals, and reused. Depending on the dyestuff and degree of accuracy required, analysis and reconstitution can be performed using a spectrophotometer or using rule-of-thumb estimates based on operating experience.

Two alternative approaches to dyebath reconstitution that have been explored at Mill Y-4 are presented in this report. These alternatives are as follows:

Alternative 1. Pumping the exhausted dyebath to a holding tank, while the product is rinsed in the same machine in which it was dyed. Once the dyed yarn has been removed, and undyed yarn has been loaded, the exhausted dyebath is returned to the machine and reconstituted.

Alternative 2. Removing the dyed yarn from the exhausted dyebath and placing it in a separate dye machine for rinsing. Simultaneously another batch of undyed yarn is placed into the original machine containing the exhausted dyebath, and this dyebath is reconstituted.

This section discusses and compares these alternatives as an introduction to specific applications in Sections IV, V, and VI.

TECHNICAL FEASIBILITY AND DESIGN CRITERIA

Literature and Previous Applications

Virtually all literature documenting experience with dyebath reconstitution have investigated Alternative 1, the use of holding tanks. No references providing information on Alternative 2 were found. The exclusive use of Alternative 1 is warranted for certain segments of the textile industry. For example, it is generally impractical for carpet dyers to move carpet from one dye machine to another simply to achieve rinsing. However, at mills where the dyed products are items such as yarn or piece goods, either of the alternatives listed above may be applicable.

General Considerations

The most desirable alternative at a particular mill will depend on a number of circumstances. Factors to be considered include the following:

1. Effect on product quality. Will product quality be adversely affected if the dyed goods are removed from the dye machine prior to rinsing and/or not rinsed immediately?

2. Level of production at the mill. Is excess dye machine capacity available for the foreseeable future; if so, can the idle dye machines be converted to holding tanks to reduce capital costs for Alternative 1? Is excess dye machine capacity presently available, but production requirements for the future uncertain; if so, does the flexibility offered by Alternative 2 provide the most attractive situation for initial and/or long-term reconstitution efforts?

3. Labor requirements. Will the amount of labor involved in transferring dyed goods elsewhere from the dye machine for rinsing adversely affect productivity or manpower requirements?

4. Volume of rinse water required. Can rinse water be used to rinse more than one batch of goods under Alternative 2; if so, how much will water use and wastewater volumes be reduced as a result?

5. Amount of energy savings. Is the temperature at which the dyed goods can be safely removed for rinsing low enough for undyed goods to be loaded; if so, does Alternative 2 provide a substantial energy savings relative to Alternative 1?

6. Space available for reconstitution equipment. Do space limitations preclude, limit, or otherwise affect the feasibility of installing holding tanks for Alternative 1; if this is the principal limitation to reconstitution, is Alternative 2 practical at the mill?

Item 1, the effect on product quality, is obviously the most important factor to be considered in an evaluation of reconstitution alternatives. If rinsing in situ is required, than Alternative 2 cannot be applied. However, the effect on product quality can be easily determined by simulation at most mills without additional capital investment, and should be assessed prior to additional investigation of and/or commitment to any single alternative.

Design Criteria

Design criteria for reconstitution are straightforward regardless of the alternative. Most of the criteria deal with factors such as initial and final dyebath temperature, dye and auxiliary chemical makeup requirements, number of batches processed per reconstitution series, etc., and are more dependent upon the type of dyeing being performed than the reconstitution alternative employed.

The holding tanks for Alternative 1 should be insulated, closed top, vertical fiberglass vessels to maximize heat retention and minimize space requirements. Each holding tank at Mill Y-4 requires a capacity of 2,300 gallons. Existing equipment is utilized under Alternative 2.

ECONOMIC FEASIBILITY

Table III-1 summarizes the relative economics of the dyebath reconstitution alternatives described. Relative economics rather than complete economics are presented to increase the general applicability of this information. Specific economic evaluations for reconstitution

TABLE III-1
RELATIVE ECONOMICS*
DYEBATH RECONSTITUTION ALTERNATIVES**

	Alternative 1	Alternative 2
Annual Operation and Maintenance Costs		
Pumping to Elevated Storage Tanks	$80	--
Additional Labor	--	$3,600
Annual Savings		
Water Supply	--	--
Sewer Use Charges	--	--
Auxiliary Chemicals	--	--
Energy	--	--
Capital Costs		
Required Equipment	$12,300	--

* Figures shown are for relative differences in cost or savings only. Where there was no relative difference between the alternatives, this fact is represented by a dash (--).

**Assumes reconstitution instituted at one dye machine only.

of various dyebaths (basic, disperse, bleach) using the alternatives are presented in subsequent sections. The following assumptions were employed in developing Table III-1:

- reconstitution economics developed for one dye machine only
- only relative costs and savings are presented, by representing lowest cost or savings alternative for a line item as zero (shown by a dash)
- dyebath used for dyeing five batches of yarn before being discharged
- five batches (one reconstitution series) dyed per day
- plant operates 300 days per year
- plant has excess dye machine capacity
- extra loading and unloading of machines associated with Alternative 2 requires two hours per day
- rinsing in original or other dye machine uses 2100 gallons per reconstituted batch; i.e., water use not affected by alternative selected
- auxiliary chemical savings not affected by reconstitution alternative selected
- both alternatives "return" reconstituted dyebath water to dye machine for next dyeing cycle at the maximum allowable initial temperature
- Alternative 1 requires a 2,300 gallon insulated, elevated fiberglass holding tank, pump, and plumbing modifications.

As can be seen from Table III-1, where Alternative 2 is technically feasible, it offers a chance for significant capital cost savings relative to Alternative 1. Alternative 2 requires no capital investment in new equipment; however, it is more labor intensive than Alternative 1. Significant water savings could be achieved with Alternative 2 if rinse water is used for more than one batch. In summary, Alternative 2 is seen to be the more economically attractive alternative. It takes 3½ years for the cumulative labor costs of Alternative 2 to become greater than the initial capital costs of Alternative 1. It becomes even more attractive as the number of dye machines incorporating reconstitution is increased.

ENVIRONMENTAL BENEFITS

No relative energy, water, or pollutant savings can be claimed by either of the alternatives over the other.

CONCLUSIONS

- Although dyebath reconstitution is commonly thought of as requiring a holding tank for the exhausted dyebath, alternatives are available to allow in situ reconstitution of the dyebath.
- The feasibility of a given alternative at a mill depends upon a number of factors including product type, effect on product quality, level of production, labor considerations, rinse water volumes required, available energy savings, and space restrictions.
- The use of dye machines for rinsing only should be investigated further to see if the total amount of fresh water used for rinsing each batch of dyed goods can be reduced.

SECTION IV

RECONSTITUTION OF BASIC DYEBATHS

DESCRIPTION OF MANUFACTURING PROCESS AND PROPOSED MODIFICATION

Approximately 70 percent of yarn dyeing at Mill Y-4 consists of basic dyeing of acrylic yarns. Nearly four-fifths of the total basic yarn dyeing production is performed in pressure package dye machines. A description of the dyeing sequence was presented in Section I and is not repeated here. Figure I-2 can be compared with Figure IV-1 to observe the differences between the existing basic dyeing operation and a revised dyeing operation employing reconstitution.

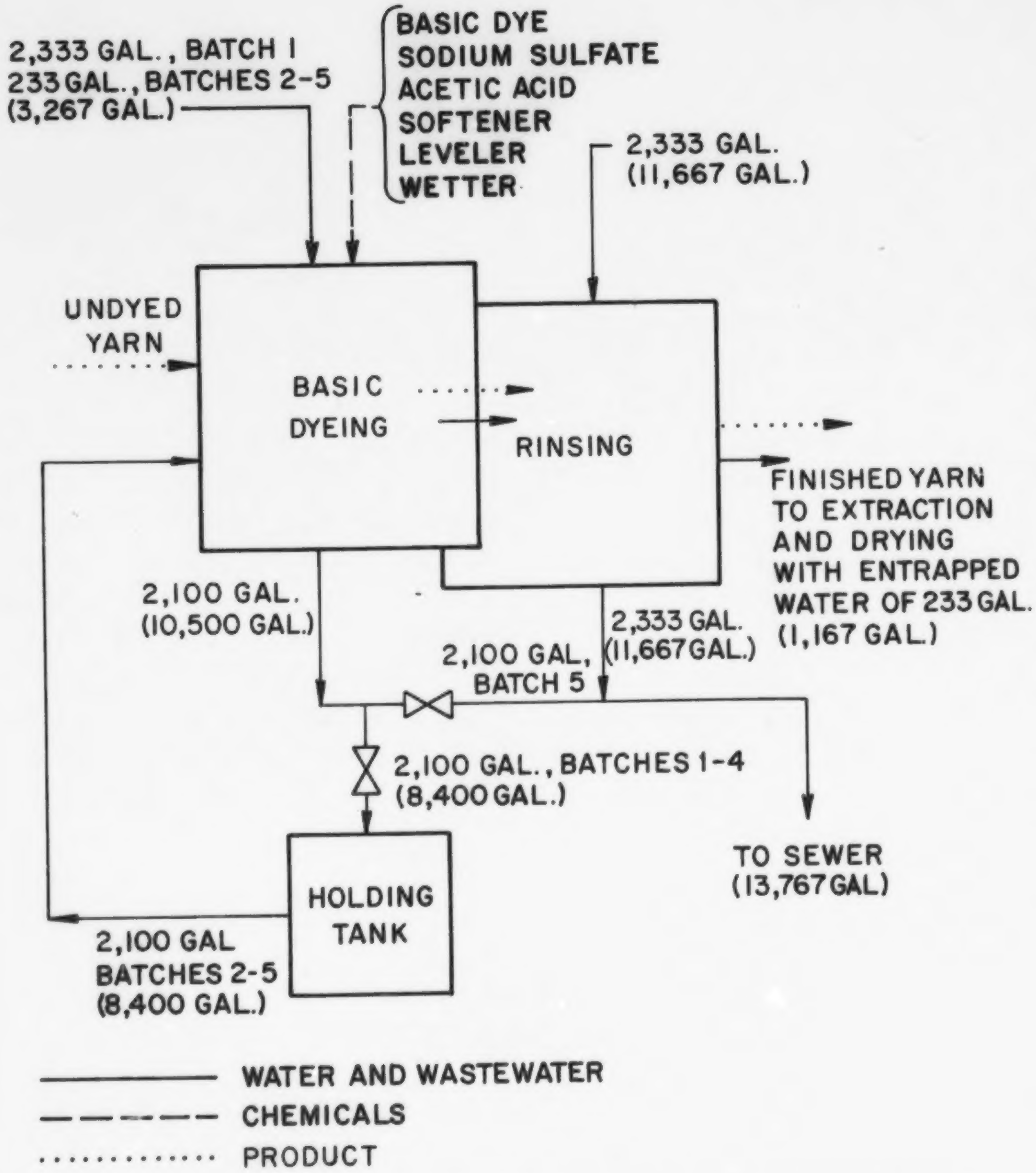
Most of the yarn dyeing machines at Mill Y-4 are similar-sized pressure machines. These machines are the most logical candidates for reconstitution at this mill, and full-scale reconstitution series have been performed with this equipment. Therefore discussions of reconstitution in this report focus on these machines.

Figure IV-1 shows a reconstitution arrangement as it would exist if Alternative 1 (see Section III) was implemented at this mill. This is the "classic" approach to reconstitution. Alternative 2, employing in situ reconstitution and a separate rinse tank, would also be an acceptable arrangement here. For illustrative purposes, Alternative 1 is presented in this section and Alternative 2 is presented in Section V.

TECHNICAL FEASIBILITY AND DESIGN CRITERIA

Literature and Previous Applications

A significant amount of research into the feasibility and technical aspects of dyebath reconstitution has been performed by the School of Textile Engineering at the Georgia Institute of Technology (Georgia Tech). Some of this research has focused on pressure batch dyeing of yarn, albeit with disperse dyes. A small amount of information on reconstitution of basic dyebaths has also been developed recently (December 1981); however, these investigations were concerned


2,333 GAL., BATCH 1
233 GAL., BATCHES 2-5
(3,267 GAL.)
BASIC DYE
SODIUM SULFATE
ACETIC ACID
SOFTENER
LEVELER
WETTER
2,333 GAL.
(11,667 GAL.)
UNDYED YARN
BASIC DYEING
RINSING
FINISHED YARN TO EXTRACTION AND DRYING WITH ENTRAPPED WATER OF 233 GAL.
(1,167 GAL.)
2,100 GAL.
(10,500 GAL.)
2,333 GAL.
(11,667 GAL.)
2,100 GAL, BATCH 5
2,100 GAL., BATCHES 1-4
(8,400 GAL.)
TO SEWER
(13,767 GAL)
HOLDING TANK
2,100 GAL
BATCHES 2-5
(8,400 GAL.)
WATER AND WASTEWATER
CHEMICALS
PRODUCT

EXAMPLE ASSUMES 1000 LB LOT SIZES, FIVE BATCHES PER RECONSTITUTION SERIES.

NUMBERS IN PARENTHESES ARE FOR ONE SERIES

FIGURE IV-1 REVISED BASIC DYEING CYCLE EMPLOYING RECONSTITUTION ALTERNATIVE I

with jet dyeing of Nomex fabric rather than pressure package dyeing of acrylic yarn. The results of these bench- and pilot-scale investigations indicate that commercially acceptable pressure yarn dyeings can be achieved with reconstituted dyebaths. A more detailed discussion of dyebath reconstitution research and applications is found in Volume 1.

Preliminary Full-Scale Investigations

Prior to initiation of this project, Mill Y-4 had performed preliminary investigations into full-scale reconstitution of basic dyebaths. This mill, in fact, was selected for the Phase II portion of this study due to their pioneering effort in the reconstitution of basic dyebaths; it was felt that Mill Y-4 provided a unique opportunity to evaluate the economic and technical feasibility of dyebath reconstitution and to draw on plant personnel expertise that would not be available at other mills. The following discussion is a summary of efforts to date.

One yarn dyeing pressure machine has been modified to enable dyebath reconstitution in conjunction with a holding tank. After dyeing, the "exhausted" dyebath from the dye machine is pumped into a holding vessel. While the exhausted dyebath is held in the tank for use as makeup in the next dyebath, the temperature usually falls from 185°F to 160°F. During this time the dyed goods are rinsed and removed, and a fresh batch of yarn loaded into the dye machine. The dyeing operation usually requires 3 basic dyes for each bath. From experience, plant personnel have learned that all basic dyes used at the mill exhaust at similar rates (approximately 95 percent) and that the product also carries about 10 percent of the water with it. Thus they know how much dye, chemicals, and make-up water are needed to reconstitute the dyebath. Most commonly the baths are reused ten times before being dumped, although running as many as 20 lots is not unusual, and they have been able to reuse the bath over 30 times in a series. When they run different colors under this arrangement, the color sequence becomes progressively deeper. Trials to date show no difference relative to conventional procedures in the ratio of acceptable to unacceptable dyeings. Mill personnel expressed great satisfaction with the savings realized by this reconstitution setup and eventually plan to institute it at other machines. The primary impediment at present appears to be finding space to install holding tanks for each machine. In addition, the mill has begun investigating alternative methods to achieve reconstitution without the use of holding tanks. Trials in which rinsing is achieved using a separate dye machine have been performed. Preliminary results indicate that this method is an acceptable means to achieve rinsing. Additional information concerning reconstitution alternatives has been presented in Section III.

Design Criteria

Much of the design criteria persented below are based on operating data developed by Mill Y-4. Reconstitution Alternative 1, the use of a holding tank, is used in this evaluation.

Although this mill has successfully and consistently achieved reconstitution trials of ten or more cycles in length, a more conservative assumption of five batches per series is used in the following analysis. W. W. Carr and F. L. Cook, in an article entitled "Savings in Dyebath Reuse Depend on Variations in Impurity Concentrations" (Reference 2), note that "long, multi-cycle sequences are not necessary to economically justify implementation of dyebath reuse. An appreciable percentage of the maximal achievable savings can be obtained with only a short sequence of runs." For example, relative to conventional dyeing a maximum savings per dye cycle of 80 percent is obtained with a 5 cycle series (based on a maximum savings per cycle of 100 percent for an infinite cycle series). This is not to suggest that there is no value in employing reconstitution series of the maximum length practical, only that long series are not necessary for a mill to obtain large savings from reconstitution.

Proper sequencing of dye cycles within a multi-shade series is important. As the proportion of dye machines at a mill at which reconstitution is practiced increases, proper scheduling may become more difficult. Shorter sequences may actually increase savings under these circumstances. For example, assume two machines are available to dye a total of 20 batches of yarn, i.e. 10 cycles per machine. It may be possible to schedule a 10 cycle reconstitution series for one machine, while dyeing ten batches conventionally in the second machine; eleven dyebath drops result. However, if four sequences of 5 batches each can be scheduled between the two machines, only four dyebath drops result, and savings can be nearly doubled. Thus it is seen that the number of machines at which reconstitution is consistently practiced is more important than lengthy reconstitution series for achieving maximum savings.

ECONOMIC FEASIBILITY

Cost savings are realized in the areas of water use, wastewater discharge, energy savings, and auxiliary chemical use. In addition to the capital costs for the holding tank, pump, pipe, valves, etc., additional expenses will be encountered for pumping and other operating costs.

Table IV-1 presents an analysis of the economics of basic dyebath reconstitution. The basis of these costs and savings is as follows:

- capital requirements for reconstitution include a 2,300-gallon, insulated, elevated fiberglass holding tank, pump, and plumbing modifications
- holding tank and related equipment must be purchased (i.e., capital equipment not already available at the mill)
- reconstitution economics developed for one dye machine only
- dyebath used for dyeing five batches of yarn before being discharged
- 1,350 batches (270 reconstitution series) dyed per year
- initial dyebath requires 2,333 gallons of water; subsequent dyebaths in reconstitution series require 233 gallons per batch as makeup
- cost of water supply is 24.63¢/1000 gallons
- cost of wastewater discharge is 58.90¢/1000 gallons
- dye and chemical costs for 5 batches dyed in the conventional manner is $195; a five-batch reconstitution series uses $87 in dyes and chemicals

TABLE IV-1
ECONOMICS
BASIC DYEBATH RECONSTITUTION*

Annual Operation and Maintenance Costs

Pumping to Elevated Storage Tanks		$ 80
Other Operation and Maintenance Costs		$ 980
	Total	$ 1,060

Annual Savings

Water Supply		$ 560
Sewer Use Charges		1,335
Auxiliary Chemicals		29,270
Energy		7,470
	Total	$38,635

Capital Costs

Holding Tank, Pump, Piping, Valves	$12,300

Payback

The payback period associated with implementing this reuse alternative is approximately 4 months.

---

*Costs and savings are for reconstitution on a full-time basis at one dye machine only. Reconstitution series are assumed at 5 batches per series.

- o energy costs are $5.64 per million Btu
- o source water available at 90°F; exhausted dyebath water at 160°F

As can be seen from the table, the payback period associated with this reconstitution scheme is approximately four months. Over three-fourths of the total savings associated with reconstitution are due to auxiliary chemical recovery. Capital costs and annual savings will be directly proportional to the number of dye machines that are apportioned to reconstitution.

ENVIRONMENTAL BENEFITS

The environmental benefits due to institution of basic dyebath reconstitution at Mill Y-4 are dependent upon the number of dye machines employed for reconstitution. For each dye machine at which reconstitution regularly occurs, water use and wastewater discharge will be reduced by 45,360 gallons per week. Assuming no buildup in successive batches, BOD_5 will be reduced by 16 pounds per day (2.1 percent of daily mill BOD_5 loading) per machine and COD will be reduced by 48 pounds per day (1.8 percent of daily mill COD loading). With reconstitution, energy savings of 26.5 million Btu per machine per week will be realized.

Characterization of exhausted basic dye wastewater from both conventional and reconstituted dyeings are presented in Tables II-1 and IV-2, respectively. There appears to be a buildup in BOD_5, COD, suspended solids, and other parameters during reconstitution, although the data presented in these tables are an insufficient basis for such a conclusion. However, this question should and can be answered in further investigations. If such a buildup does occur, the estimated reductions in pollutant loadings noted above may be optimistic.

CONCLUSIONS

- o Dyebath reconstitution has been successful in basic dyeing of acrylic yarn in full-scale operation at this mill.
- o With a payback period measured in terms of months, the economics of reconstitution at this mill are extremely attractive.
- o Considerable environmental benefits may result from the implementation of basic dyebath reconstitution.

TABLE IV-2

RECONSTITUTED BASIC DYE WASTEWATER CHARACTERIZATION

	Concentration (mg/l)		
Parameter	Reconstitution Series A Exhausted Intermediate Bath	Reconstitution Series B Exhausted Intermediate Bath	Reconstitution Series B Exhausted End Bath
pH	6.2	5.9	6.2
Temperature [°F (°C)]	181 (83)	210 (99)	203 (95)
BOD	940	1,150	1,500
COD	1,800	3,000	5,700
TS	5,380	6,400	6,210
TDS	4,670	5,760	5,460
TSS	2	13	18
Hardness (as $CaCO_3$)	< 1	< 1	< 1
Phenolics	0.046	0.066	0.093
Color (ADMI)	316	370	785
Cadmium	--	--	< 0.1
Chromium	--	--	< 0.1
Copper	--	--	< 0.1
Iron	--	--	0.50
Nickel	--	--	< 0.1
Zinc	--	--	7.7

SECTION V

RECONSTITUTION OF DISPERSE DYEBATHS

DESCRIPTION OF MANUFACTURING PROCESS AND PROPOSED MODIFICATION

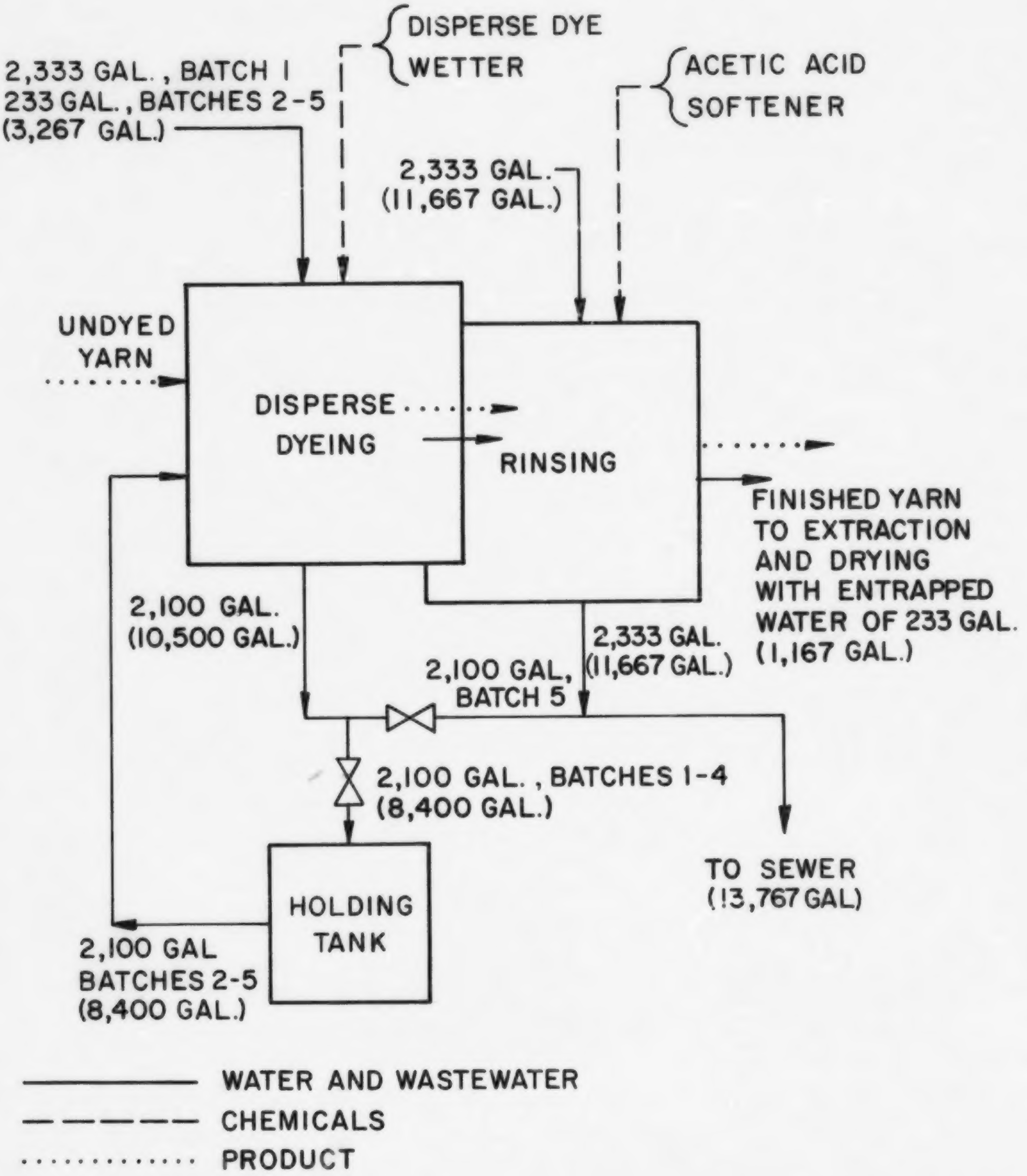
Disperse dyeing of acrylic fibers accounts for approximately 20 percent of yarn dyeing at Mill Y-4. A description of the disperse dyeing procedure was presented in Section I and is not repeated here. Figure I-3 can be compared with Figures V-1 and V-2 to observe the differences between the existing disperse dyeing operation and two alternative revised dyeing operations employing reconstitution. Figure V-1 represents Alternative 1 as presented in Section III; Figure V-2 shows Alternative 2. Additional discussion of these alternative reconstitution methods has been presented in Sections III and IV.

TECHNICAL FEASIBILITY AND DESIGN CRITERIA

Literature and Previous Applications

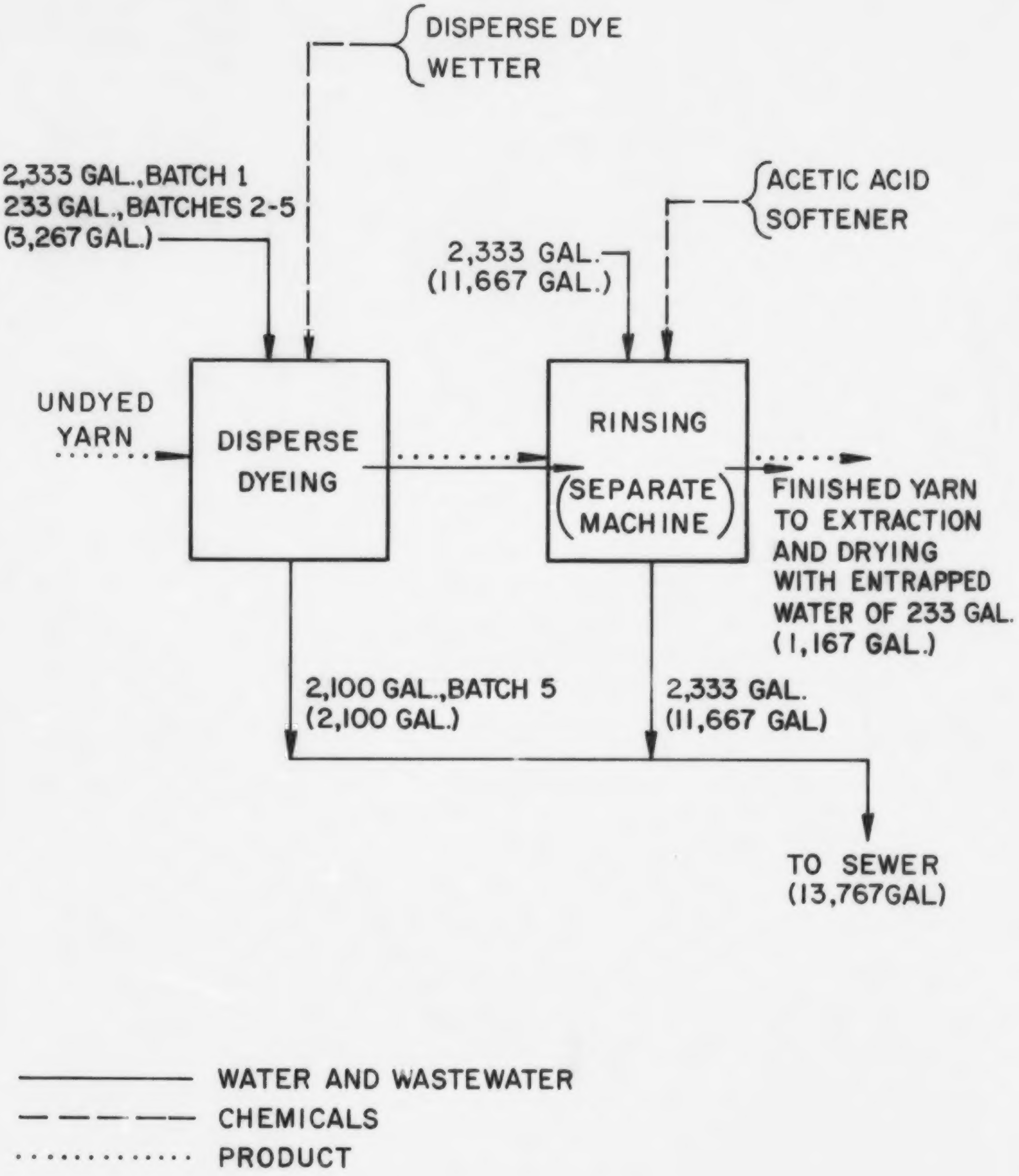
As noted in Section IV, research into reconstitution of disperse dyes used in pressure package dyeing of (polyester) yarn has been conducted at Georgia Tech. Pilot-scale reconstitution investigations into disperse dyeing of nylon and polyester carpet and polyester yarn have also been carried out at this school.

In the yarn dyeing experiments at Georgia Tech, a spun yarn package was placed in a small pressure dyeing machine. Water was added and raised to a temperature of 175°F. Acetic acid, carrier, and dye were added and circulated. The machine was then sealed as the bath was raised to 250°F. The yarn was dyed for 30 minutes before the bath was cooled to 200°F and pumped into a holding tank. While the dyed yarn was being rinsed and removed, the exhausted bath was analyzed with a spectrophotometer. The bath was then returned to the dye machine, the temperature brought to 175°F, the next package positioned, and the dye added. As many as eleven cycles were included in each of the several series that were performed in this manner. Both spun and textured yarn were evaluated, as well as single and multi-shade reconstitution series.


DISPERSE DYE
WETTER
2,333 GAL., BATCH 1
233 GAL., BATCHES 2-5
(3,267 GAL.)
ACETIC ACID
SOFTENER
2,333 GAL.
(11,667 GAL.)
UNDYED YARN
DISPERSE DYEING
RINSING
FINISHED YARN TO EXTRACTION AND DRYING WITH ENTRAPPED WATER OF 233 GAL.
(1,167 GAL.)
2,100 GAL.
(10,500 GAL.)
2,333 GAL.
(11,667 GAL.)
2,100 GAL, BATCH 5
2,100 GAL., BATCHES 1-4
(8,400 GAL.)
TO SEWER
(13,767 GAL)
HOLDING TANK
2,100 GAL
BATCHES 2-5
(8,400 GAL.)
WATER AND WASTEWATER
CHEMICALS
PRODUCT

EXAMPLE ASSUMES 1000 LB LOT SIZES, FIVE BATCHES PER SERIES
NUMBER IN PARENTHESES ARE FOR ONE SERIES.

FIGURE V-1. REVISED DISPERSE DYEING CYCLE EMPLOYING RECONSTITUTION ALTERNATIVE 1


DISPERSE DYE
WETTER
2,333 GAL., BATCH 1
233 GAL., BATCHES 2-5
(3,267 GAL.)
ACETIC ACID
SOFTENER
2,333 GAL.
(11,667 GAL.)
UNDYED YARN
DISPERSE DYEING
RINSING
(SEPARATE MACHINE)
FINISHED YARN TO EXTRACTION AND DRYING WITH ENTRAPPED WATER OF 233 GAL.
(1,167 GAL.)
2,100 GAL., BATCH 5
(2,100 GAL.)
2,333 GAL.
(11,667 GAL)
TO SEWER
(13,767GAL)
WATER AND WASTEWATER
CHEMICALS
PRODUCT

EXAMPLE ASSUMES 1000 LB LOT SIZES, FIVE BATCHES PER SERIES
NUMBER IN PARENTHESES ARE FOR ONE SERIES.

FIGURE V-2. REVISED DISPERSE DYEING CYCLE EMPLOYING RECONSTITUTION ALTERNATIVE 2

The color formulations in these experiments consisted of light shades, medium shades, and dark shades. Additional details of dyebath reconstitution research and applications are found in Volume 1.

Pilot Scale Results

Mill Y-4 has performed laboratory studies of disperse dyebath reconstitution. The investigations were performed using 70-lb lot sizes. These efforts demonstrated to the mill that each exhausted bath to be reconstituted would have to be spectrophotometrically analyzed subsequent to solvent extraction of the dye.

Unlike basic dyes, nearly all of which exhaust at a 94 to 96 percent rate in each dyebath, disperse dyes used at this mill are extremely variable in exhaustion rates. Therefore, experience alone is insufficient to enable successful reconstitution of exhausted disperse dyebaths, and analytical methods are required. With soluble dyes (such as acid, basic, direct, and reactive) spectrophotometric analysis can be carried out directly on the dyebath. Disperse dyes are not water soluble, however, and modified techniques are required to correctly analyze these solutions. A technique used at Georgia Tech to analyze disperse dyebaths involves placing the exhausted dyebath sample in a separatory funnel and adding a measured amount of organic solvent such as benzene or toluene. The mixture is shaken to extract the dye into the organic layer, and a spectrophotometric analysis conducted on the dissolved dye in the organic layer.

Design Criteria

Reconstitution Alternative 2, the use of a separate dye machine for rinsing, is used in this evaluation for three reasons. First, the lack of readily available space in the dyehouse at this mill limits convenient placement of additional holding tanks. Second, Alternative 2 should not have a detrimental effect on product quality. And third, as presented in the Section III discussion of relative economics, it takes over three years before the additional labor costs of this alternative equal the capital costs of Alternative 1.

As noted in Section IV, proper sequencing of the dye cycles within a multi-shade series is important, and in some circumstances fairly short reconstitution series may be desirable. Thus, even though the cycle time for disperse dying is short, due to the relatively small amount of disperse dyeing (i.e., 20 percent) performed at Mill Y-4, it is unlikely that reconstitution sequences of more than 5 cycles could be typically scheduled. In addition, reconstitution of disperse dyebaths will likely be performed at one or at most two dye machines (exclusive of any machines for rinsing).

ECONOMIC FEASIBILITY

Cost savings are realized in the areas of water use, wastewater discharge, energy savings, and auxiliary chemical use. In addition to the capital costs for analytical and related equipment, additional operating costs will be encountered for labor and various operating supplies.

Table V-1 presents an analysis of disperse dyebath reconstitution. The basis of these costs and savings is as follows:

- reconstitution economics developed for one dye machine only
- dyebath used for dyeing five batches of yarn before being discharged
- 1,350 batches (270 reconstitution series) dyed per year
- labor requirement for transporting yarn to a separate machine for rinsing is 2 hours per day
- labor requirement for solvent extraction, analysis, calculations, and adjustments averages 3-1/3 hours per day.
- initial dyebath requires 2,333 gallons of water; subsequent dyebaths in reconstitution series require 233 gallons per batch as makeup.
- cost of water supply is 24.63¢/1000 gallons
- cost of wastewater discharge is 58.90¢/1000 gallons
- dye and chemical costs for 5 batches dyed in the conventional manner is $75; a five-batch reconstitution series uses $45 in dyes and chemicals

TABLE V-1
ECONOMICS
DISPERSE DYEBATH RECONSTITUTION*

Annual Operation and Maintenance Costs

Labor - Yarn Transport		$ 3,600
Labor - Dyebath Analysis		6,000
Operating Supplies		5,040
	Total	$14,640

Annual Savings

Water Supply		$ 560
Sewer Use Charges		1,340
Auxiliary Chemicals		8,130
Energy		7,470
	Total	$17,500

Capital Costs

Spectrophotometer and Microprocessor		$ 9,450
	Total	$ 9,450

Payback

Payback on capital costs is approximately 3-1/3 years.

---

*Costs and savings are for reconstitution on a full-time basis at one dye machine only. Reconstitution series are assumed at 5 batches per series.

- energy costs are \$5.64 per million Btu
- source water available from effluent heat exchanger at 90°F; exhausted dyebath water at 160°F
- mill has excess dye machine capacity.

As can be seen from Table V-1, the payback period associated with disperse dyebath reconstitution at this mill is a little over three years. Total capital costs are approximately two-thirds of one year's operating costs. Capital costs do not increase as the number of machines employing disperse dyebath reconstitution increases. If the number of machines employing disperse dyebath reconstitution is raised to two, the period required for capital cost payback is reduced by half.

ENVIRONMENTAL BENEFITS

The environmental benefits due to implementation of disperse dyebath reconstitution at this mill depend upon the extent to which this approach is employed. For each dye machine at which disperse dyebath reconstitution regularly occurs, water use and wastewater discharge will be reduced by 45,360 gallons per week. There is insufficient information to characterize BOD_5 and COD reductions. Energy savings of 26.5 million Btu per machine per week will be realized.

Characterization of exhausted disperse dye wastewater is presented in Table V-2.

CONCLUSIONS

- A considerable amount of research on disperse dyebath reconstitution has been conducted at Georgia Tech. Disperse dyebath reconstitution has been shown successful on a pilot-scale by these researchers.
- The economics of disperse dyebath reconstitution are not nearly as attractive as basic dyebath reconstitution at this mill due to a number of factors: lower per cycle auxiliary chemical savings, higher capital costs due to the need for analytical equipment, higher labor costs due to the need for dyebath analysis, and fewer total machines at which disperse dyebath reconstitution can be located. With a payback period of 1½ to 3½ years, disperse dyebath reconstitution is only marginally attractive at this mill from an economic viewpoint.

TABLE V-2

DISPERSE DYE WASTEWATER CHARACTERIZATION

	Average Concentration (mg/l)*	
Parameter	Dyebath	Rinse Water
pH (median)	8.1	6.3
Temperature [°F (°C)]	208 (98)	121 (49)
BOD	290	89
COD	1,240	290
TS	660	290
TDS	600	330
TSS	2	7
Hardness (as $CaCO_3$)	< 1	< 1
Phenolics	< 0.051	< 0.040
Color (ADMI)	1,410	200

Selected metals were also analyzed in the wastewater from one disperse dyebath sample and the results were as follows: Cd - < 0.1 mg/l; Cr - < 0.1 mg/l; Cu - < 0.1 mg/l; Fe - 0.1 mg/l; Ni - < 0.1 mg/l; Zn - < 0.1 mg/l.

*Based on 3 grab samples unless otherwise noted.

- Moderate environmental benefits may result from the implementation of disperse dyebath reconstitution.

SECTION VI

RECONSTITUTION OF BLEACH BATHS

DESCRIPTION OF MANUFACTURING PROCESS AND PROPOSED MODIFICATION

Bleaching of acrylic fibers accounts for approximately 10 percent of yarn finishing at Mill Y-4. A description of the bleaching operation was presented in Section I and is not repeated here. Figure I-4 can be compared with Figure VI-1 to observe the differences between the existing bleaching procedure and the revised bleaching procedure employing reconstitution. Due to the several baths and rinses in a bleach cycle, Alternative 1 (reconstitution using a holding tank) is the only practical reconstitution alternative for bleaching at this mill.

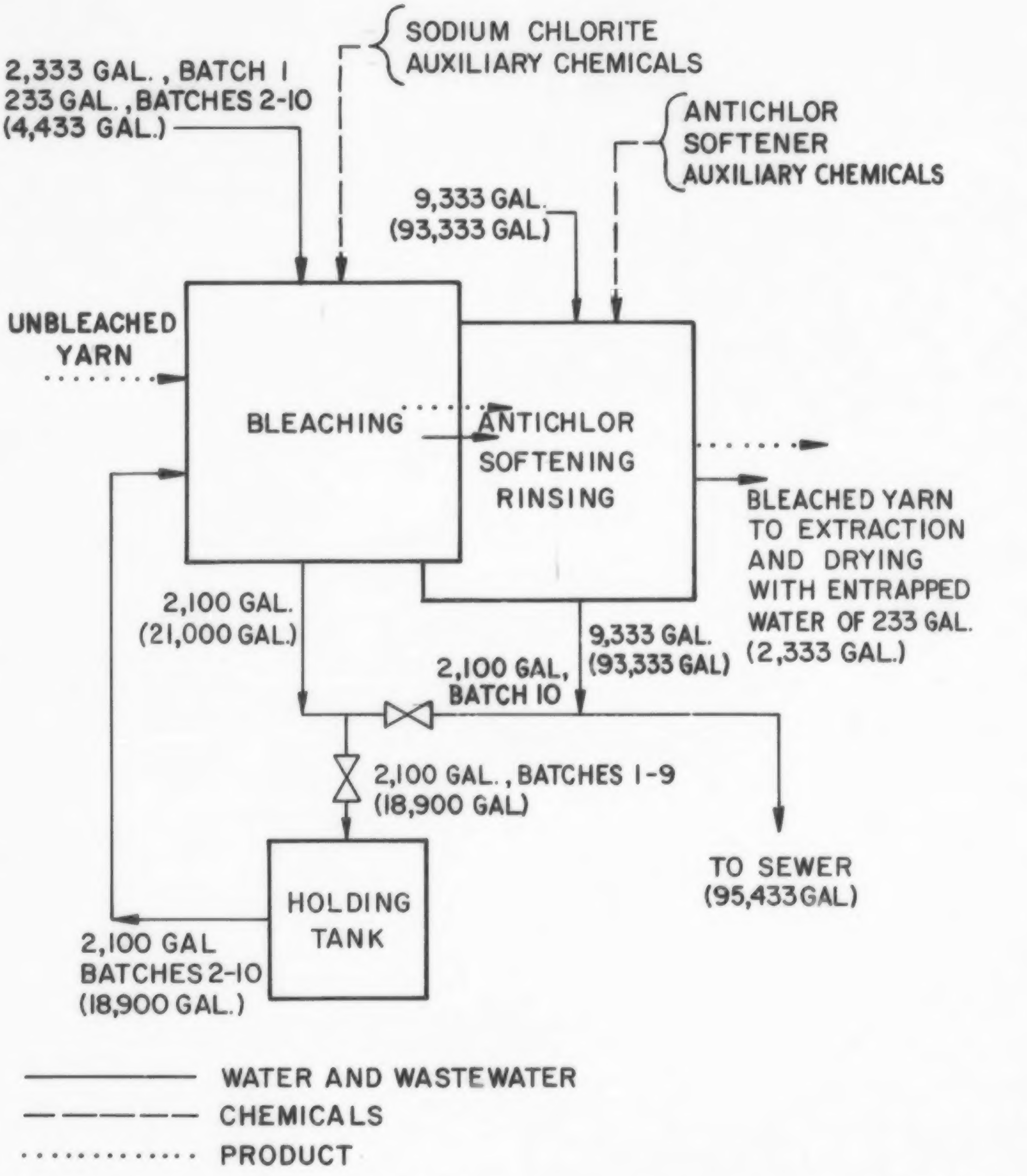
TECHNICAL FEASIBILITY AND DESIGN CRITERIA

Literature and Previous Applications

Although substantial amounts of research have been performed on reconstitution of dyebaths, little or no information on the reconstitution of bleach baths has been published. A general discussion of reconstitution, primarily as related to dyebaths, is presented in Volume 1.

Preliminary Full-Scale Investigations

In addition to performing preliminary investigations into full-scale reconstitution of basic dyebaths, this mill has also evaluated full-scale reconstitution of bleach baths. After bleaching is performed, the exhausted bleach bath is pumped to a holding tank while dechlorination, rinsing, and softening are all separately performed in the original dye machine to complete the bleaching cycle. Once the bleached yarn is removed, and fresh yarn added to machine, the exhausted bleach bath is returned from the holding tank and reconstituted to initiate the next cycle. When a reconstitution sequence of bleaching is performed at this mill, the bleach bath is reconstituted over and over again until many cycles have been run or the mill is through with bleaching.


SODIUM CHLORITE
AUXILIARY CHEMICALS
2,333 GAL., BATCH 1
233 GAL., BATCHES 2-10
(4,433 GAL.)
ANTICHLOR
SOFTENER
AUXILIARY CHEMICALS
9,333 GAL.
(93,333 GAL)
UNBLEACHED YARN
BLEACHING
ANTICHLOR
SOFTENING
RINSING
BLEACHED YARN TO EXTRACTION AND DRYING WITH ENTRAPPED WATER OF 233 GAL.
(2,333 GAL.)
2,100 GAL.
(21,000 GAL.)
9,333 GAL.
(93,333 GAL)
2,100 GAL,
BATCH 10
2,100 GAL., BATCHES 1-9
(18,900 GAL)
TO SEWER
(95,433 GAL)
HOLDING TANK
2,100 GAL
BATCHES 2-10
(18,900 GAL.)
WATER AND WASTEWATER
CHEMICALS
PRODUCT

EXAMPLE ASSUMES 1000 LB LOT SIZES, TEN BATCHES PER SERIES
NUMBERS IN PARENTHESES ARE FOR ONE SERIES

FIGURE VI-1. REVISED BLEACHING CYCLE EMPLOYING RECONSTITUTION.

Design Criteria

Unlike dyeing, bleaching is very predictable and routine from one batch to the next. Batches do not need to be sequenced in a particular order as with dyeing, and hence scheduling is not a consideration at a particular machine as long as there is bleaching to be done. No analysis of the exhausted bleach bath is required. The bleaching agent is assumed to be completely exhausted, while the degree of exhaustion in auxiliary chemicals is based on experience. Mill experience has shown that the quality of finished product is not affected by bleach reconstitution series of 10 cycles or more.

ECONOMIC FEASIBILITY

Cost savings are realized in the areas of water use, wastewater discharge, energy savings, and chemical use. In addition to the capital costs for the holding tank and related equipment (e.g. pump, piping, valves, etc.), a small additional operating cost for pumping will be experienced.

Table VI-1 presents an analysis of the economics of bleach bath reconstitution. The basis of these costs and savings is as follows:

- capital requirements for reconstitution include a 2,300-gallon, insulated, elevated fiberglass holding tank, pump, and plumbing modifications
- holding tank and related equipment must be purchased (i.e. capital equipment not already available at mill)
- reconstitution economics developed for one dye machine only
- bath used for bleaching ten batches of yarn before being discharged
- 1,350 batches (135 reconstitution series bleached per year)
- plant operates 300 days per year
- initial bleach cycle requires 2,333 gallons of water; subsequent bleach baths in reconstitution series require 233 gallons per batch as makeup
- cost of water supply is 24.63¢/1000 gallons

TABLE VI-1
ECONOMICS
BLEACH BATH RECONSTITUTION*

Annual Operation and Maintenance Costs

Pumping to Elevated Storage Tanks		$ 80
Other Operation and Maintenance Costs		980
	Total	$ 1,060

Annual Savings

Water Supply		$ 630
Sewer Use Charges		1,500
Chemicals		15,080
Energy		8,400
	Total	$25,610

Capital Costs

Holding Tank		$ 6,000
Pump, Piping, Valves, and Other Costs		6,300
	Total	$12,300

Payback

Payback on capital costs is approximately 6 months.

---

*Costs and savings are for reconstitution on a full-time basis at one dye machine only. Reconstitution series are assumed at 10 batches per series.

- cost of wastewater discharge is 58.90¢/1000 gallons
- chemical costs (except completely exhausted chemicals) for 10 batches bleached in the conventional manner (first step only) is $246; a ten-batch reconstitution series (first step only) uses $134 in chemicals (not including completely exhausted chemicals)
- energy costs are $5.64 per million Btu
- source water available at 90°F; exhausted bleach bath water at 160°F

As can be seen from the table, the payback period associated with bleach bath reconstitution using holding tanks at this mill is approximately 6 months. Nearly 60 percent of the savings are due to chemical recovery, while another one-third of the savings are due to reduced energy costs.

With only 10 percent of yarn dyeing at this mill attributable to bleaching, only 1 dye machine should be allocated for reconstitution of bleach baths.

ENVIRONMENTAL BENEFITS

The environmental benefits due to the allocation of one dye machine for full-time bleach bath reconstitution are water use and wastewater discharge savings of 51,000 gallons per week and weekly energy savings of 29.8 million Btu. BOD_5 discharged will be reduced by 16 pounds per day (2.1 percent of daily mill BOD_5 loading), while COD will be reduced by 8 pounds per day (0.3 percent of daily mill COD loading).

Characterization of exhausted bleach wastewater from both conventional and reconstituted baths are presented in Tables VI-2 and VI-3, respectively. In comparing the first column of Table VI-2 with Table VI-3, note that some buildup in pollutant concentrations does occur due to bleach bath reconstitution and reuse.

CONCLUSIONS

- Bleach bath reconstitution has been successful in bleaching of acrylic yarn in full-scale operation at this mill.

TABLE VI-2

BLEACH WASTEWATER CHARACTERIZATION

	Average Concentration (mg/l)*				
Parameter	Bleach Bath	Bleach Rinse	Dechlorination Bath	Dechlorination Rinse	Softening Bath
pH (median)	3.6	6.3	6.0**	6.3**	5.8
Temperature [°F (°C)]	204 (96)	92 (33)	131 (55)**	88 (31)**	105 (41)
BOD	320	36	22	12	18
COD	855	150	140**	94**	89
TS	1,380	330	880	330**	360
TDS	1,160	340	880	330**	340
TSS	< 4	< 4	6	6**	8
Hardness (as $CaCO_3$)	< 1	< 1	4**	1**	< 1
Phenolics	< 0.040	< 0.040	< 0.040**	< 0.040**	< 0.040**
Color (ADMI)	3,080	130	36	< 24**	7.5
Cadmium	< 0.1**	--	< 0.1**	--	< 0.1**
Chromium	< 0.1**	--	< 0.1**	--	< 0.1**
Copper	< 0.1**	--	< 0.1**	--	< 0.1**
Iron	< 0.3**	--	0.22**	--	0.12**
Nickel	< 0.1**	--	< 0.1**	--	< 0.1**
Zinc	< 0.1**	--	0.13**	--	< 0.1**

* Based on 2 grab samples unless otherwise noted.
** Based on 1 grab sample.

TABLE VI-3

RECONSTITUTED BLEACH WASTEWATER CHARACTERIZATION

Parameter	Concentration (mg/l)	
	Exhausted Intermediate Bath	Exhausted End Bath
pH	6.2	6.3
Temperature [°F (°C)]	162 (72)	171 (77)
BOD	620	600
COD	4,600	2,700
TS	3,830	4,600
TDS	3,070	3,980
TSS	2	8
Hardness (as $CaCO_3$)	< 1	< 1
Phenolics	0.042	< 0.040
Color (ADMI)	24	168
Cadmium	--	< 0.1
Chromium	--	< 0.1
Copper	--	< 0.1
Iron	--	1.1
Nickel	--	< 0.1
Zinc	--	0.14

- With a payback period of six months, the economics of reconstitution at this mill are attractive.
- Significant environmental benefits result from the implementation of bleach bath reconstitution.

REFERENCES

1. Perkins, W. S., J. F. Judkins, Jr., and W. D. Perry. "Renovation of Dyebath Water by Chlorination or Ozonation," Textile Chemist and Colorist, Vol. 12, Nos. 8-10 (August-October, 1980), pp. 182-272.

2. Carr, W. W. and F. L. Cook. "Savings in Dyebath Reuse Depend on Variations in Impurity Concentrations," Textile Chemist and Colorist, Vol. 12, No. 5 (May 1980), pp. 106-110.